# ATIONAL POPLAR RIVER WATER QUALITY STUDY





## Appendix D: Uses and Water Quality Objectives

1979

# INTERNATIONAL POPLAR RIVER WATER QUALITY STUDY



## Appendix D: Uses and Water Quality Objectives



Prepared by the Uses and Water Quality
Objectives Committee of the International
Poplar River Water Quality Board,
International Joint Commission

1979

# LETTER OF TRANSMITTAL

Ottawa, Ontario, Canada
Helena, Montana, United States
March, 1979

Dr. Robert K. Lane, Co-Chairman
Dr. Robert C. Averett, Co-Chairman
International Poplar River
Water Quality Board

Gentlemen:

It is our pleasure to transmit to you the report "Water Uses and Water Quality Objectives for the International Poplar River, 1979", prepared by the Uses and Water Quality Objectives Committee.

The report presents, in detail, present and reasonably foreseeable future water uses and the conditions of quality required to support these water uses in the International Poplar River Basin. It reflects the best scientific information on cause/effect relationships of pollutants to receptors that is available. The report also discusses the impact of the Saskatchewan Power Commission's operations and future water uses on water quality in relation to the recommended water quality objectives. The conclusions and recommendations offered reflect the best judgement of the Committee.

The report evaluates scientific data and practical and reliable methods for detecting and measuring such data, and it develops this information arranged in annexes to the report.

The committee is of the opinion that the information contained in this report will be of use and value to the water resource managers of this basin and to a large number of people throughout the basin who are concerned with achieving a high level of water quality for the Poplar River and its tributaries.

We express pleasure in having had the opportunity to undertake this assignment.

Respectfully,

D Scott Brown

D. Scott Brown, Co-Chairman

S.W. Reeder

S.W. Reeder, Co-Chairman

## LIST OF COMMITTEE MEMBERS

| | |
|---|---|
| D. Scott Brown | Montana Department of Natural Resources and Conservation, Helena, Montana (U.S. Co-Chairman). |
| Robert J. Burm | U.S. Environmental Protection Agency, Denver, Colorado. (U.S. Secretary). |
| D.R. Cameron | Agricultural Research Station, Swift Current, Saskatchewan. |
| Don A. Fast | Environment Saskatchewan, Regina, Saskatchewan. (Canadian Secretary). |
| Abe Horpestad | Montana Department of Health, Helena, Montana. |
| S.W. Reeder | Environment Canada, Ottawa, Ontario. (Canadian Co-Chairman). |
| J.R. Sims | Plant and Soil Science Department, Montana. State University, Bozeman, Montana. |
| Don T. Waite | Environment Saskatchewan, Regina, Saskatchewan. |
| Mike Watson | Morrison - Maierle, Inc. Helena, Montana. |

## SUMMARY AND GENERAL RECOMMENDATIONS

The report presents, in the best scientific judgement of the Committee, the present and reasonably foreseeable water uses in the Poplar River Basin and the water quality requirements to protect these uses within the limitations of the best available scientific knowledge and information.

The multipurpose water quality objectives recommended for the waters of the basin including international crossing points are summarized, here, as a master table. The scientific information used in establishing these objectives is presented, with references, by designated water use in Annexes A through D to this report. Annex E to this report presents sampling and analytical methodologies recommended for use in the implementation of these objectives. The users of this report are urged to refer to these annexes to receive maximum value of the data presented.

Comparisons of predicted historical water quality and predicted future water quality, in accordance with the reasonably foreseeable water uses, with the recommended water quality objectives are presented. The effects of the 600 megawatt power plant operation in Canada on the quality of the waters of the East Poplar and Poplar Rivers are discussed.

The general recommendations of the Committee are:

1. the water quality objectives set out in this report be accepted for use in the Poplar River basin and that they be required to be reviewed at least every five years.

2. water quality monitoring programs be initiated throughout the basin and especially at the international border to ensure that the water quality objectives are not violated. The monitoring programs to be conducted in accordance with the methodologies described in Annex E.

## MASTER TABLE

Multipurpose Water Quality Objectives
for the Poplar River Basin Including International Border Crossings
(Total constituents unless otherwise stated)

| | | Not to Exceed Limit |
|---|---|---|
| Chemical | | |
| Aluminum (Al), dissolved | mg/L | 0.1 |
| Ammonia ($NH_3$), free | mg/L | 0.02 |
| Boron (B) | mg/L | 5.0 - Long term (10 yrs) |
| | mg/L | 8.0 - Short term (3 mos) |
| Cadmium (Cd) | mg/L | 0.0012 |
| Chromium (Cr) | mg/L | 0.05 |
| Copper (Cu), dissolved | mg/L | 0.005 |
| Copper (Cu) | mg/L | 1.0 |
| Fluoride (F) | mg/L | 1.5 |
| Lead (Pb) | mg/L | 0.03 |
| Mercury (Hg), dissolved | mg/L | 0.0002 |
| Mercury (Hg), whole fish | mg/kg | 0.5 |
| Nitrate (N) | mg/L | 10.0 |
| Oxygen ($O_2$), dissolved | mg/L | >5.0 (April 10 to May 15) |
| | mg/L | >4.0 (remainder of year) |
| pH | Units | >6.5 & <0.5 above natural |

## MASTER TABLE (CONT'D)

Multipurpose Water Quality Objectives for the
Poplar River Basin Including the International Border Crossings
(Total constituents unless otherwise stated)

| Parameter | | Not to Exceed Limit |
|---|---|---|
| SAR | mg/L | 10 |
| Sulfate ($SO_4$) | mg/L | 800 |
| Total Dissolved Solids (TDS) | mg/L | 1000 - Long-term (10 yr) |
| | mg/L | 1500 - Short-term (3 mos) |
| Zinc (Zn) | mg/L | 0.03 |
| **Physical** | | |
| Temperature | C° | Natural (April 10 to May 15) |
| | C° | <30 (remainder of year) |
| **Microbiological** | | |
| Coliforms, geometric mean | | |
| -fecal | Counts/100 mL | 1000 |
| -total | Counts/100 mL | 5000 |
| Coliforms, maximum densities | | |
| -fecal | Counts/100 mL | 2000 |
| -total | Counts/100 mL | 20 000 |

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# GENERAL INTRODUCTION

This report presents the findings, conclusions and recommendations of the Uses and Water Quality Objectives Committee of the International Poplar River Water Quality Board that, in the best scientific judgement of the Committee, complies with its terms of references to:

1) review and report on present and reasonably foreseeable future uses of water in the Poplar River Basin, particularly those in the East Poplar River. These should include, but are not limited to:

    a) municipal and domestic water supply;
    b) irrigation, stockwatering, and other general agricultural uses;
    c) maintenance of indigenous fisheries;
    d) industrial uses; and
    e) contact sports and other recreational and aesthetic considerations.

2) examine the water quality criteria required to support identified water uses, and develop and recommend water quality objectives to be met at the International Boundary to protect the most sensitive identified downstream water use.

3) forecast the impact of SPC operations on water quality in relation to recommended water quality objectives.

The Committee, in carrying out these terms of reference, was basically concerned that:

1) the development of the 600 megawatt power plant on the East Poplar River would cause injury to health and property in contravention of Article IV of the Boundary Waters Treaty of 1909;

2) the apportioning of water quantity in the basin in accordance with the Apportionment Agreement as recommended by the International Souris-Red River Engineering Board would substantially affect the water uses, as well as the water quality supporting these uses; and

3) the basin waters, both quantity and quality wise, would support the reasonably foreseeable future water uses.

The report, therefore, focuses primarily on the water quality effects of the 600 megawatt power plant under development, north of the International Boundary, on the East Poplar River; the Apportionment Agreement and the reasonably foreseeable water uses on the quality of the waters in the basin. Although the report deals with the quality of the waters throughout the basin (figure I), emphasis was placed on the quality and quantity of water required to meet the present and reasonably foreseeable water uses in the United States.

The report presents the findings of the Committee in three major parts. Part I deals with the water uses of the basin, both present and reasonably foreseeable future uses. Part II deals with water quality in relation to the development and recommendation of water quality objectives, a forecast of the impact of present and future water uses in relation to recommended water quality objectives, and method requirements for monitoring for compliance of water quality objectives. Part III presents the scientific bases from which the multiple-use water quality objectives were developed. This material is presented as Annexes A through D with each annex representing a major water use in the basin.

Due to basic and fundamental disagreement with the findings and conclusions presented in this committee's report, other documents presenting minority findings and conclusions are attached.

Consideration of existing uses accounts for all existing water rights in the Poplar River Basin, except the reserved rights of the Fort Peck, Sioux and Assiniboine Tribes. Existing use rights and the Indian reserved rights constitute all existing water rights, which are interest in real property. However, this Committee has not considered water rights in this basin.

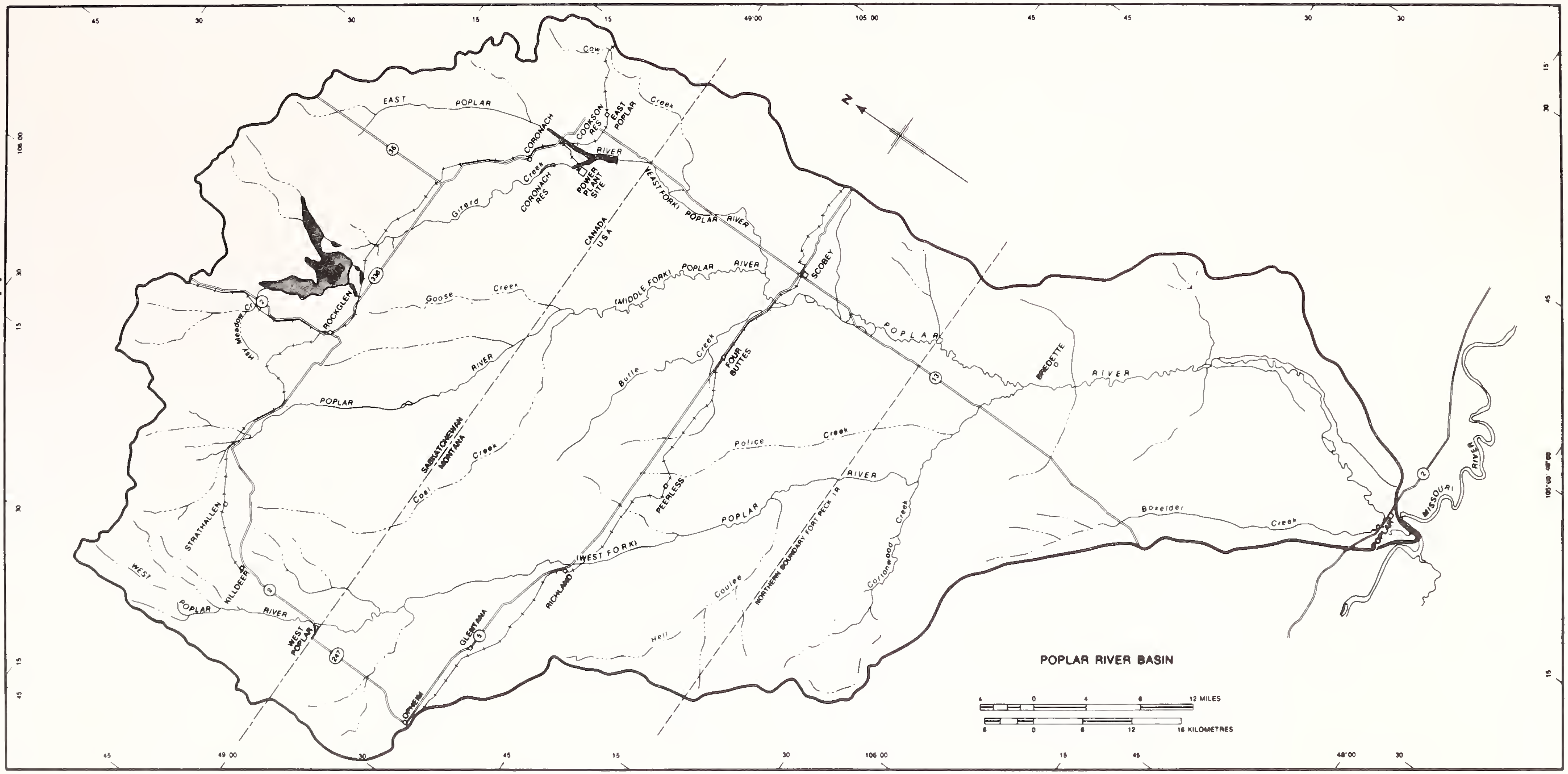


Figure 1. Rivers of the Poplar River Basin.

# PART I

# AN INVENTORY OF EXISTING AND PROJECTED FUTURE USES OF WATER IN THE POPLAR RIVER BASIN

## INTRODUCTION

The geomorphology of the Poplar River Basin is typical of the glaciated northern prairie region with gently rolling topography. The soils of the basin range from sandy to silt-loam alluvial deposits along the water courses to clay-loam glacial till deposits on the uplands. A mean annual precipitation of 30 to 40 centimetres (12 to 16 inches) and 110 to 120 frost free days per year render the basin semi arid. Grasslands are the natural climax stage of plant succession; however, much of the basin has been transformed into cropland and pasture.

Approximately 7000 to 8000 people inhabit this strictly rural basin. Roughly two-thirds of the basin's population lives in the United States.

Historically, the principal uses of Poplar River waters have been related to agriculture.

Hundreds of small earthen dams have been constructed over the past half-century to trap spring runoff water in the numerous coulees and minor tributary streams. The reservoirs formed are used primarily for watering livestock, but increased evaporation from them represents a significant loss of water and must therefore be considered a use.

Spring water spreading and full service (gravity and pumping) irrigation systems have also been used extensively over the period of record (1931 through the present) and their use has increased significantly, particularly in the portion of the basin between the international boundary and the Fort Peck Indian Reservation boundary (see Figure 2).

The year 1931 is one of the earliest for which records are available. Total water use in the basin in 1931 was approximately 2200 cubic decametres (1800 acre feet), and more than 99 percent of the total was used in Montana.[1]

In 1950, total water use in the basin was approximately 4200 cubic decametres (3400 acre feet). The increase was due principally to evaporation from the increasing number of agricultural reservoirs in the basin and, to a lesser degree, to an increase in spring water spreading.

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[1] Historical water use figures were obtained from Tables A-5 and A-8 of Appendix A: Existing and Historical Surface Water Use, Report of the International Souris-Red Rivers Engineering Board, Poplar River Task Force, January, 1976.

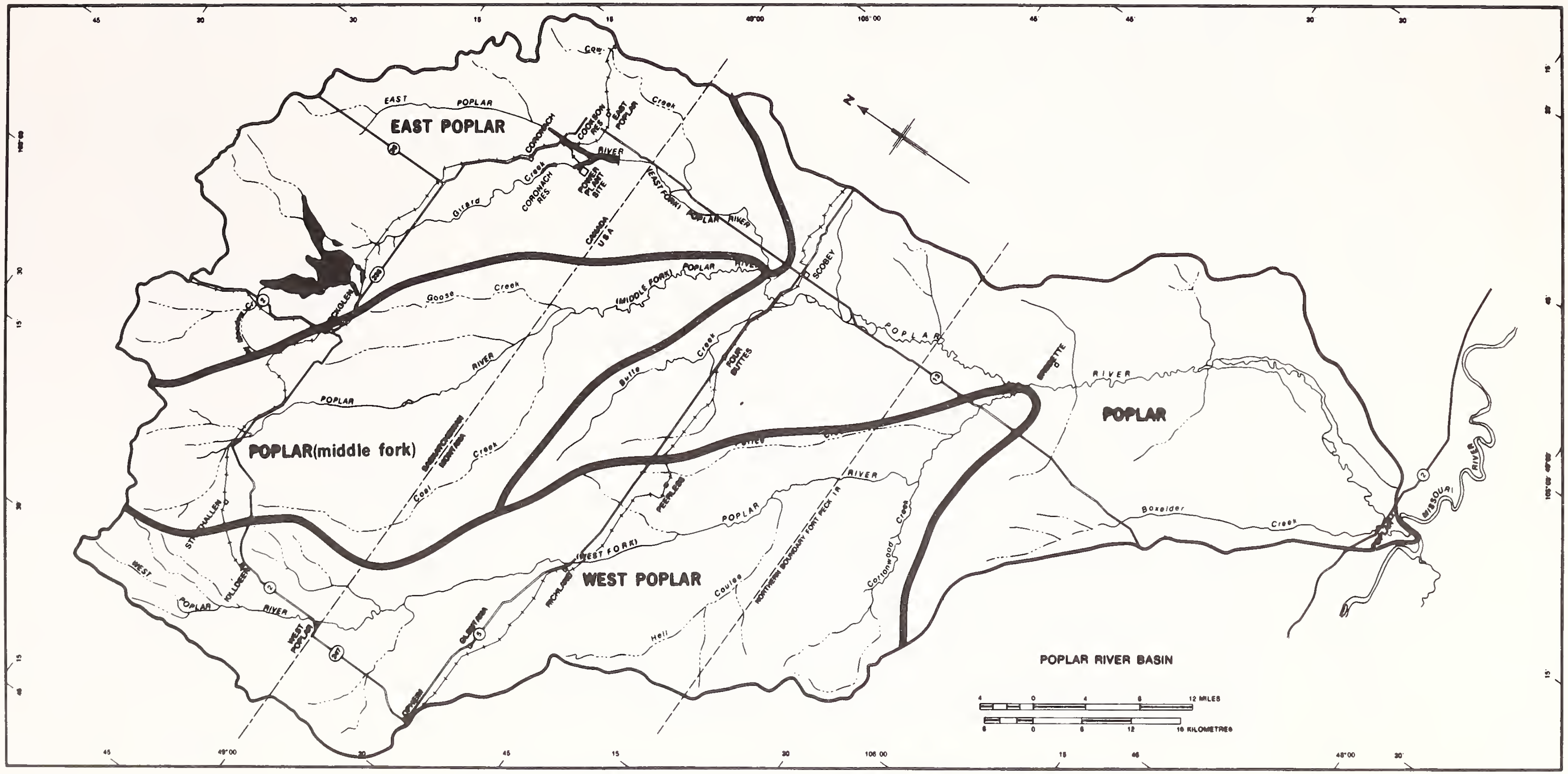


Figure 2 Subbasins of the Poplar River Basin, as used in this report.

Water usage in Saskatchewan in 1950 had increased 480 cubic decametres (390 acre feet) over 1931; however, uses in Montana still accounted for roughly 90 percent of the estimated basin total in 1950.

By 1970, a significant increase in full service irrigation and spring water spreading, particularly in Montana, had raised water uses in the basin to an estimated total of 11 700 cubic decametres (9500 acre feet). All but 345 cubic decametres (280 acre feet) of that total is attributed to agricultural uses and 84 percent of the water used in the basin was used in Montana. From these statistics, it is clear that the water usage has increased substantially in the Poplar River basin and the increase has been principally for agricultural purposes. However, the typically variable water supply from one year to the next has greatly affected agricultural water use in the basin. For example, agricultural use in Montana during 1961 totaled a relatively low 4600 cubic decametres (3700 acre feet). The following year, agricultural use was approximately 8100 cubic decametres (6600 acre feet) or an 80 percent increase over the previous year. Streamflow records of the two years under consideration show that the total volume of Poplar River water discharged into the Missouri River in 1962 was roughly four times greater than the amount discharged in 1961. Simply stated, when the water has been available, it has been used.

Prior to 1975, the greatest use of the basin's water occurred in 1972. An estimated total of 12 670 cubic decametres (10 276 acre feet) of water was used, of which all but approximately 370 cubic decametres (300 acre feet) can be attributed to agricultural uses.

Instream uses of the basin's waters are equally important, but it is very difficult to quantify such uses. The principal instream uses are related to recreation and the maintenance of stream flows sufficient to support existing aquatic organisms. The Biological Resources Committee has discussed instream uses in its report (Appendix C).

# EXISTING USES

## General

Water availability during 1975 was at record or near record levels throughout the Poplar River Basin. A record maximum instantaneous discharge of 114 cubic metres per second (4020 cfs) was measured on the East Poplar River at the international boundary on April 23, 1975. The previous maximum instantaneous discharge measured at that point was 78 cubic metres per second (2760 cfs) in 1939. Consequently, the existing (1975) level of uses is greater than any previous year on record. An estimated total of 13 557 cubic decametres (10 995 acre feet) of water was used in the basin in 1975. Table I-1 summarizes existing uses and presents a breakdown of uses by subbasin (Figure 2) and by use category.

The existing level of uses presented in Table I-1 is not in complete agreement with the existing level of uses presented in Appendix A of the International Souris-Red Rivers Engineering Board, Poplar River Task Force Report, January, 1976. Existing and Historical Surface Water Use; from hereon referred to as Task Force. This committee's examination of background information, personal communications with key individuals and close, firsthand observations, including two separate flights over the basin, have resulted in necessary revisions to the existing use figures presented by the Task Force. The rationale supporting those revisions will be fully explained; however, in the majority of cases, where the existing uses, as presented by the Task Force are not in question, the assumptions underlying the reporting of existing uses will not be discussed in depth.

## Existing Municipal Uses

Municipal water use in the basin is limited to the village of Coronach, Saskatchewan and the city of Scobey, Montana.

Coronach, which had a population of approximately 300 in 1975, receives its water supply from a well adjacent to Coronach Reservoir. The water in this well is pumped from a shallow (10 to 12 metres) sand and gravel aquifer. Recent tests indicate an abnormally high yield for such an aquifer. Recharge from the adjacent reservoir is believed to be responsible for the high yield.

Scobey, which had a population of approximately 1500 in 1975, has three shallow wells adjacent to the Poplar River, one mile west of the city. Two pumps presently in use have a combined capacity of 2839 litres per minute (750 gallons per minute), but the wells are capable of supplying up to 3407 litres per minute (900 gallons per

TABLE I-1a

Existing Consumptive Water Uses in the Poplar River Basin[a]
(Cubic Decametres)

| | MUNICIPAL | DOMESTIC | IRRIGATION | | | RESERVOIR EVAPORATION | |
|---|---|---|---|---|---|---|---|
| | | | Water Spreading | Sprinkling | Flooding | | Subtotals |
| **Saskatchewan** | | | | | | | |
| West Poplar River Subbasin | 0 | 57 | 31 | 0 | 0 | 284 | 372 |
| Poplar River Subbasin | 0 | 168 | 0 | * | 64 | 0 | 232 |
| East Poplar River Subbasin | 44 | 464 | 169 | * | 105 | 481 | 1263 |
| Column Subtotals | 44 | 689 | 200 | * | 169 | 765 | 1867 |
| **Montana** | | | | | | | |
| Exclusive of Reservation | | | | | | | |
| West Poplar River Subbasin | 0 | 470 | 408 | 777 | 111 | - | 1766 |
| Poplar River Subbasin (middle fork) | 0 | 150 | 90 | 567 | 952 | - | 1759 |
| Poplar River Subbasin | 432 | 412 | 377 | 679 | 2525 | - | 4425 |
| East Poplar River Subbasin | 0 | 129 | 1051 | 0 | 181 | - | 1361 |
| Column Subtotals | 432 | 1161 | 1926 | 2023 | 3769 | - | 9311 |
| Fort Peck Indian Reservation | | | | | | | |
| West Poplar River Subbasin | 0 | 109 | 48 | 0 | 0 | - | 157 |
| Poplar River Subbasin | 0 | 989 | 321 | 274 | 640 | - | 2224 |
| Column Subtotals | 0 | 1098 | 369 | 274 | 640 | - | 2381 |
| Grand Totals | 476 | 2948 | 2495 | 2297 | 4578 | 765 | 13 559 |

(a) Limited sprinkling irrigation may be practiced in Saskatchewan; however, a distinction was not made between flooding and sprinkling irrigation in the information provided. It is presumed the use figures provided for flooding include all existing full service irrigation.

TABLE I-1b

Existing Consumptive Water Uses in the Poplar River Basin[a]
(acre feet)

| | MUNICIPAL | DOMESTIC | IRRIGATION | | | RESERVOIR EVAPORATION | |
|---|---|---|---|---|---|---|---|
| | | | Water Spreading | Sprinkling | Flooding | | Subtotals |
| Saskatchewan | | | | | | | |
| West Poplar River Subbasin | 0 | 46 | 25 | 0 | 0 | 230 | 301 |
| Poplar River Subbasin | 0 | 136 | 0 | * | 52 | 0 | 188 |
| East Poplar River Subbasin | 36 | 376 | 137 | * | 85 | 390 | 1024 |
| Column Subtotals | 36 | 558 | 162 | * | 137 | 620 | 1513 |
| Montana | | | | | | | |
| Exclusive of Reservation | | | | | | | |
| West Poplar River Subbasin | 0 | 381 | 331 | 630 | 90 | - | 1432 |
| Poplar River Subbasin (middle fork) | 0 | 122 | 73 | 460 | 772 | - | 1427 |
| Poplar River Subbasin | 350 | 334 | 306 | 551 | 2048 | - | 3589 |
| East Poplar River Subbasin | 0 | 105 | 852 | 0 | 147 | - | 1104 |
| Column Subtotals | 350 | 942 | 1562 | 1641 | 3057 | - | 7552 |
| Fork Peck Indian Reservation | | | | | | | |
| West Poplar River Subbasin | 0 | 88 | 39 | 0 | 0 | - | 127 |
| Poplar River Subbasin | 0 | 802 | 260 | 222 | 519 | - | 1803 |
| Column Subtotals | 0 | 890 | 299 | 222 | 519 | - | 1930 |
| Grand Totals | 386 | 2390 | 2023 | 1863 | 3713 | 620 | 10 995 |

(a) Limited sprinkling irrigation may be practiced in Saskatchewan; however, a distinction was not made between flooding and sprinkling irrigation in the information provided. It is presumed the use figures provided for flooding include all existing full service irrigation.

minute). A 378 540 litre (100 000 gallon) storage tank is located in Scobey.

The estimated use of 432 decametres (350 acre feet) of water in 1975 by Scobey's population of 1500 represents an average of 795 litres (210 gallons) per person per day, whereas the estimated use of 44 cubic decametres (36 acre feet) of water in 1975 by Coronach's population of 300 represents an average of 405 litres (107 gallons) per person per day.

In both cases, the alluvium deposits from which municipal water supplies are drawn are recharged by the Poplar River, but fluctuations of well water elevations with respect to time have not been monitored. It is believed that any change in surface water quality would in time affect the quality of municipal water supplies.

For the purpose of incorporating municipal water use into the water quality model, the monthly percentage use figures, as presented in table I-2, were reported to the Surface Water Quality Committee.

TABLE I-2

Monthly Percentage Breakdown for Municipal Water Use in the Poplar River Basin

| | | | |
|---|---|---|---|
| January | 4% | July | 16% |
| February | 4% | August | 15% |
| March | 5% | September | 10% |
| April | 6% | October | 7% |
| May | 10% | November | 5% |
| June | 14% | December | 4% |
| | | Total | 100% |

(Monthly percentage use figures were provided by the Montana Water Quality Bureau and may reflect Canadian municipal use).

## Existing Domestic Use

Domestic water uses generally include livestock watering and rural household and garden irrigation needs. However, the Task Force determined that rural household and garden irrigation needs are relatively insignificant in this basin. Therefore, only those uses related to livestock watering were estimated and reported in the Task Force Report. While this committee recognizes that rural household and garden irrigation requirements are probably small in relation

to livestock use and evaporation, it also recognizes a need to monitor private wells, with respect to water quality and well level fluctuations. The Committee assumed that this matter will be reviewed by the Groundwater Quality and Quantity Committee.

Existing domestic uses reported in Table I-1 include evaporation losses from the numerous reservoirs in the basin, as well as the amounts actually consumed by livestock. With the aid of aerial photographs, the Task Force determined that nearly 800 small stockwater reservoirs had been constructed in the basin by 1975. It was also determined that evaporation from them constitutes a greater use than the amount actually consumed by livestock. Of the estimated 2947 cubic decametres (2390 acre feet) of water attributed to domestic uses in 1975, slightly less than 1233 cubic decametres (1000 acre feet) was consumed by livestock and about 1763 cubic decametres (1430 acre feet) evaporated. The aerial photographs also show that 610 reservoirs, or roughly three-fourths of the total number of stockwater reservoirs in the basin, are in Montana.

There is an additional 765 cubic decametres (620 acre feet) of water evaporated from three larger reservoirs in Saskatchewan (Table I-1). These reservoirs, Clark Bridge Reservoir, Coronach Reservoir and West Poplar Reservoir serve a variety of purposes, including municipal, domestic, irrigation and probably recreational uses. No such large projects have been constructed in Montana.

Although the reservoirs, large or small, are probably filled each year during the spring runoff, when a surplus of water is available, evaporation from them constitutes a rather significant use of the basin's water. In 1975, evaporation from all reservoirs, excluding Cookson Reservoir, resulted in the loss of slightly more than 2466 cubic decametres (2000 acre feet) of water. This amount is nearly 20 percent of the total amount of water attributed to all existing uses in the basin.

## Existing Irrigation Use

Irrigation practices in the Poplar River basin have been placed into three categories for the purposes of this report. They are (a) spring water spreading, (b) sprinkler irrigation and (c) flooding irrigation by gravity or pumping.

The two categories of full service irrigation, sprinkling and flooding by gravity or pumping, differ only slightly with respect to monthly and seasonal requirements. Therefore, they will be discussed together.

## Spring Water Spreading

Spring water spreading, or backflooding with spreader dikes, is an irrigation practice that permits a single application of water to a field or pasture during the peak runoff period. More than one application may be possible in some years. But frequently the volume of runoff, or the timing of it, has been such that even a single application has not been possible.

Water spreading systems in the basin are designed to receive approximately 30 centimetres (12 inches) of water; however, the existing moisture content of the soil and, generally, frozen ground during the runoff period permit only about 20 to 25 centimetres (8 to 10 inches) of water to be consumed (Task Force, 1976).

In 1975, water was abundant in the basin during runoff and as a result, it is estimated that slightly more than 972 hectares (2200 acres) were irrigated in this manner. The water use figures of 2494 cubic decametres (2023 acre feet) reported for backflooding (Table I-1), differs from the sum of the use figures given in the Task Force Report for backflooding. Review of the background information on water spreading in Montana revealed that an arithmetic error had been made and that 759 hectares (1875 acres) was actually irrigated in this manner in 1975, exclusive of the Fort Peck Indian Reservation (Montana Department of Natural Resources and Conservation, 1978). The use figures presented by the Task Force for backflooding in Saskatchewan and on the reservation are unchanged in this report.

Acreage figures for all existing irrigation in Montana, including the reservation, are presented in Table I-3. Acreage figures for irrigation in Saskatchewan are not available in this report. Information from the Task Force Report provides sufficient information on uses in Saskatchewan.

The amount of water consumed by water spreading systems in Montana, including those on the reservation, was determined by multiplying 25.4 centimetres (0.833 foot) by the total area irrigated in this manner. The Task Force assumed 25.4 centimetres (0.833 foot , or ten inches), to be the water requirement per hectare (per acre) for water spreading systems in Montana. The same was assumed for water spreading systems in Saskatchewan.

Depending upon the conditions of the soil, the timing and magnitude of the runoff, crop types and other factors, the actual amount of water consumed varies. The water trapped by water spreading systems is often in excess of the amount required to saturate the soil. In such cases, the water remaining after three of four days is

TABLE I-3a

Estimated Existing (1975) Irrigated Acreage in the Poplar River Basin: Montana
(Hectares)

| | Water Spreading | Sprinkling | Flooding | Subtotals |
|---|---|---|---|---|
| Exclusive of Reservation | | | | |
| West Poplar River Subbasin | 161 | 111 | 15 | 287 |
| Poplar River Subbasin (middle fork) | 37 | 81 | 126 | 244 |
| Poplar River Subbasin | 149 | 97* | 333 | 579 |
| East Poplar River Subbasin | 414 | 0 | 26 | 440 |
| Subtotals | 761 | 289 | 500 | 1550 |
| Fort Peck Indian Reservation | | | | |
| West Poplar River Subbasin | 19 | 0 | 0 | 19 |
| Poplar River Subbasin | 126 | 39 | 85 | 250 |
| Subtotals | 145 | 39 | 85 | 269 |
| Totals | 906 | 328 | 585 | 1819 |

*: observed in 1978.

TABLE I-3b

Estimated Existing (1975) Irrigated Acreage in the Poplar River Basin: Montana
(acres)

| | Water Spreading | Sprinkling | Flooding | Subtotals |
|---|---|---|---|---|
| Exclusive of Reservation | | | | |
| West Poplar River Subbasin | 397 | 274 | 36 | 707 |
| Poplar River Subbasin (middle fork) | 88 | 200 | 310 | 598 |
| Poplar River Subbasin | 367 | 240* | 823 | 1430 |
| East Poplar River Subbasin | 1023 | 0 | 65 | 1088 |
| Subtotals | 1875 | 714 | 1234 | 3823 |
| Fort Peck Indian Reservation | | | | |
| West Poplar River Subbasin | 47 | 0 | 0 | 47 |
| Poplar River Subbasin | 312 | 96 | 210 | 618 |
| Subtotals | 359 | 96 | 210 | 665 |
| Totals | 2234 | 810 | 1444 | 4488 |

*: observed in 1978.

released and becomes runoff once again; its quality only slightly diminished. The Uses and Water Quality Objectives Committee does not view such excess water as return flow water; rather a return flow, with respect to spring backflooding, is defined as water that passes through soil, becomes groundwater and eventually returns to a stream.

The Surface Water Quality Committee is reporting on both the amount and timing of return flows. It should be pointed out that some of the return water probably comprises a percentage of the amount of water required by downstream users, although it would be difficult to quantify this amount.

## Irrigation by Gravity or Pumping - Sprinkling and Flooding

The principal crops irrigated in the basin by full service irrigation methods are alfalfa and grass hays. Wheat and barley are also irrigated by sprinkling and flooding, but on a relatively small scale. The periodic rotation of an irrigated field from alfalfa to barley or wheat reduces the likelihood of disease as well as root build up by alfalfa. According to a few irrigators, who participated in a public meeting of the Uses and Water Quality Objectives Committee in Scobey, irrigated grains have proved to be excellent cash crops in certain years. Still, alfalfa is the principal crop irrigated.

The monthly and seasonal water requirements for alfalfa in the basin are presented in Table I-4. According to the U.S. Soil Conservation Service (1974) the basin is in a moderately high consumptive use area. The net-irrigation requirement is 49 centimetres (19.35 inches).

An overall system efficiency rating of 70 percent is assumed to be representative of sprinkling systems in the basin. Therefore, a season total of 173.4 centimetres per hectare (27.65 inches per acre) is the desired diversion requirement. In the case of full service flooding irrigation, where an overall system efficiency rating of 65 percent is assumed, a season total of 186.6 centimetres per hectare (29.76 inches per acre) is the desired diversion requirement.

## Sprinkling

A total of 328 hectares (810 acres) of crops is estimated to have been irrigated by sprinkling in Montana in 1975. While limited sprinkler irrigation may exist in Saskatchewan, no distinction was made between sprinkler and flooding irrigation in the background information provided.

TABLE I-4a

Monthly and Seasonal Consumptive Use Requirements and Diversion Requirements for Alfalfa in the Poplar River Basin
(Centimetres)

| | Total Consumptive Use | Effective Rainfall | Net Irrigation Requirement | Diversion Requirement 70% Efficient | Diversion Requirement 65% Efficient |
|---|---|---|---|---|---|
| May | 9.40 | 3.35 | 6.05 | 8.64 | 9.30 |
| June | 14.48 | 5.66 | 8.81 | 12.60 | 13.56 |
| July | 19.08 | 3.30 | 15.77 | 22.53 | 24.26 |
| August | 15.60 | 2.57 | 13.03 | 18.62 | 20.04 |
| September | 7.44 | 1.96 | 5.49 | 7.85 | 8.43 |
| Season Total | 66.00 | 16.84 | 49.15 | 70.24 | 75.59 |

(Source: U.S. Soil Conservation Service, 1974)

TABLE I-4b

Monthly and Seasonal Consumptive Use Requirements and Diversion Requirements for Alfalfa in the Poplar River Basin
(inches)

| | Total Consumptive Use | Effective Rainfall | Net Irrigation Requirement | Diversion Requirement 70% Efficient | Diversion Requirement 65% Efficient |
|---|---|---|---|---|---|
| May | 3.70 | 1.32 | 2.38 | 3.40 | 3.66 |
| June | 5.70 | 2.23 | 3.47 | 4.96 | 5.34 |
| July | 7.51 | 1.30 | 6.21 | 8.87 | 9.55 |
| August | 6.14 | 1.01 | 5.13 | 7.33 | 7.89 |
| September | 2.93 | 0.77 | 2.16 | 3.09 | 3.32 |
| Season Total | 25.98 | 6.63 | 19.35 | 27.65 | 29.76 |

(Source: U.S. Soil Conservation Service, 1974).

TABLE I-5a

Monthly and Seasonal Diversion Requirements for Existing Sprinkling Irrigation in the Poplar River Basin: Montana
(Cubic Decametres)

| Exclusive of Reservation | May | June | July | August | September | Subtotals |
|---|---|---|---|---|---|---|
| West Poplar River Subbasin | 95 | 138 | 250 | 206 | 88 | 777 |
| Poplar River Subbasin (middle fork) | 69 | 101 | 182 | 150 | 64 | 566 |
| Poplar River Subbasin | 84 | 121 | 219 | 180 | 76 | 680 |
| East Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Column Subtotals | 248 | 360 | 651 | 536 | 228 | 2023 |
| Fort Peck Indian Reservation | | | | | | |
| West Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 33 | 49 | 88 | 73 | 31 | 274 |
| Column Subtotals | 33 | 49 | 88 | 73 | 31 | 274 |
| Grand Totals | 281 | 409 | 739 | 609 | 259 | 2297 |

TABLE I-5b

Monthly and Seasonal Diversion Requirements for Existing Sprinkling Irrigation in the Poplar River Basin: Montana (acre feet)

| Exclusive of Reservation | May | June | July | August | September | Subtotals |
|---|---|---|---|---|---|---|
| West Poplar River Subbasin | 77 | 112 | 203 | 167 | 71 | 630 |
| Poplar River Subbasin (middle fork) | 56 | 82 | 148 | 122 | 52 | 460 |
| Poplar River Subbasin | 67 | 98 | 178 | 146 | 62 | 551 |
| East Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Column Subtotals | 200 | 292 | 529 | 435 | 185 | 1641 |
| Fort Peck Indian Reservation | | | | | | |
| West Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 27 | 40 | 71 | 59 | 25 | 222 |
| Column Subtotals | 27 | 40 | 71 | 59 | 25 | 222 |
| Grand Totals | 227 | 332 | 600 | 494 | 210 | 1863 |

Table I-5 summarizes the monthly and seasonal diversion requirements for existing sprinkler irrigation in the basin, based upon the requirements of alfalfa shown in Table I-4 at a 70% efficiency rating.

## Flooding

Flooding irrigation by pumping or gravity constitutes the single greatest use of water in the basin. A total of 4578 cubic decametres (3713 acre feet) of water is estimated to have been used in the basin in this matter in 1975. This represents the application of water to approximately 608 hectares (1500 acres). As in the case of water spreading, acreage estimates are not provided in this report for Saskatchewan. For acreage estimates of full service flooding in Montana refer to Table I-3.

Table I-6 presents monthly and seasonal diversion requirements for existing flooding irrigation by gravity or pumping in Montana. An overall system efficiency rating of 65 percent is assumed.

It must be emphasized that the diversion requirements presented in Tables I-4, I-5, I-6 represent the desired diversion requirement. It is not known, in a basin wide sense, how frequently or infrequently these requirements are satisfied in the Poplar River Basin. The Task Force determined that irrigators have continued to apply water to crops even though water availability has allowed an average of only 2.4 applications per season over many years. However, interviews with individual irrigators in Montana indicate that many of them apply water over the entire irrigation season, year after year. They admit that even though stream flows may be extremely low - perhaps nearly zero flow - they will pump water out of deep pools to irrigate. The pools are apparently being recharged by groundwater.

The Task Force determined that the gross irrigation depletion requirement (diversion requirement) is 48.2 centimetres per hectare (7.69 inches per acre) per application. At an average of 2.4 applications, the seasonal diversion requirement would be 115.8 centimetres per hectare (18.46 inches per acre). That is considerably less than the requirement given in Table I-4. However, in years of abundant water, the Task Force determined that as many as four applications could have occurred.

In such cases, it is reasonable to assume that slightly more than 188 centimetres of water per hectare (30 inches of water per acre) would have been diverted. The year 1975 was probably such a year. The existing use figures presented in the previous tables, with respect to irrigation, are considered by members of this Committee

TABLE I-6a

Monthly and Seasonal Diversion Requirements for
Existing Flooding Irrigation By Gravity or Pumping
in the Poplar River Basin: Montana
(Cubic Decametres)

| Exclusive of Reservation | May | June | July | August | September | Subtotals |
|---|---|---|---|---|---|---|
| West Poplar River Subbasin | 14 | 20 | 36 | 30 | 12 | 112 |
| Poplar River Subbasin (middle fork) | 118 | 168 | 306 | 253 | 107 | 952 |
| Poplar River Subbasin | 314 | 446 | 811 | 670 | 284 | 2525 |
| East Poplar River Subbasin | 25 | 36 | 64 | 35 | 22 | 182 |
| Column Subtotals | 471 | 670 | 1217 | 988 | 425 | 3771 |
| Fort Peck Indian Reservation | | | | | | |
| West Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 79 | 115 | 206 | 170 | 70 | 640 |
| Column Subtotals | 79 | 115 | 206 | 170 | 70 | 640 |
| Grand Totals | 550 | 785 | 1423 | 1158 | 495 | 4411 |

TABLE I-6b

Monthly and Seasonal Diversion Requirements for
Existing Flooding Irrigation By Gravity or Pumping
in the Poplar River Basin: Montana
(acre feet)

| Exclusive of Reservation | May | June | July | August | September | Subtotals |
|---|---|---|---|---|---|---|
| West Poplar River Subbasin | 11 | 16 | 29 | 24 | 10 | 90 |
| Poplar River Subbasin (middle fork) | 96 | 136 | 248 | 205 | 87 | 772 |
| Poplar River Subbasin | 255 | 362 | 658 | 543 | 230 | 2048 |
| East Poplar River Subbasin | 20 | 29 | 52 | 28 | 18 | 147 |
| Column Subtotals | 382 | 543 | 987 | 800 | 345 | 3057 |
| **Fort Peck Indian Reservation** | | | | | | |
| West Poplar River Subbasin | 0 | 0 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 64 | 93 | 167 | 138 | 57 | 519 |
| Column Subtotals | 64 | 93 | 167 | 138 | 57 | 519 |
| Grand Totals | 446 | 636 | 1154 | 938 | 402 | 3576 |

to be reasonably representative of the actual amount of water required. Thus, in most years, return flows and groundwater augmentation to the surface water supply must play a significant role in permitting the level of irrigation that occurs in the basin, particularly in Montana.

## PROJECTED FUTURE USES

### Future Uses in Saskatchewan

Projections of future water use by Saskatchewan are limited to the amount of water available from the apportionment recommendation. This was accomplished by assuming that roughly one-half of the average annual flow of the Poplar River, as determined at the international boundary, would eventually be used in Saskatchewan.

Table I-7 presents projected future uses for the years 1985 and 2000. The use figures reported here are essentially those presented in the Task Force Report, Appendix C: Probably Future Use. However, minor variations are evident as the use figures and the area wide percentage distributions were manipulated in order to construct a schedule of full usage of Saskatchewan's share of the water, as stated above. As is evident in Table I-7 the full usage of Saskatchewan's share of West Poplar River water was deemed improbable by the year 2000. The projected use of 521 cubic decametres (423 acre feet) of water in that subbasin represents approximately 20 percent of Saskatchewan's share. The projected use figures of 8471 and 8674 cubic decametres (6870 and 7035 acre feet) for the Poplar River and East Poplar River subbasins, respectively, represent all of Saskatchewan's share in each case.

### Future Municipal Use

The village of Coronach will absorb a major part of the population increase anticipated with the completion and operation of the power plant nearby. By 1985, with one unit operating, it is projected that 185 cubic decametres (150 acre feet) of water will be required each year for municipal use. By 2000, with two units operating, a requirement of 802 cubic decametres (650 acre feet) is projected for Coronach. In order to meet the projected requirement for the year 2000 it will probably be necessary to divert water from a source other than the East Poplar River. The sum of the existing and projected future uses of the East Poplar River exceeds one-half of the average annual flow by approximately 411 cubic decameters (333 acre feet). Thus, the figure of 411 cubic decameters (333 acre feet) appears as a municipal use under uses of Poplar River Subbasin (Table I-7).

Current plans for the disposal of municipal waste water call for disposal by effluent irrigation. Since most of this water will be lost by evaporation or consumed by plants, it is assumed that no municipal waste water will be returned directly to either the surface water or groundwater.

## TABLE I-7a

Projected Future Water Uses in the Poplar River Basin: Saskatchewan[a]
(cubic decametres)
(Including existing uses listed in Table I-1)

| | Municipal | | Domestic | | Irrigation Water Spreading | | Irrigation Full Service | | Reservoir Evaporation | | Industrial | | Wildlife | | Total Use By Subbasin | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 |
| West Poplar River Subbasin | 0 | 0 | 72 | 72 | 43 | 43 | 123 | 123 | 284 | 284 | 0 | 0 | 0 | 0 | 522 | 522 |
| Poplar River Subbasin | 0 | 411 | 213 | 213 | 0 | 0 | 90 | 90 | 0 | 4439 | 0 | 3133 | 185 | 185 | 488 | 8471 |
| East Poplar River Subbasin | 185 | 391 | 588 | 588 | 237 | 237 | 147 | 147 | 4439 | 4439 | 2688 | 2688 | 185 | 185 | 8469 | 8675 |
| Column Subtotals | 185 | 802 | 873 | 873 | 280 | 280 | 360 | 360 | 4723 | 9162 | 2688 | 5821 | 370 | 370 | 9479 | 17 668 |

[a] These estimates were developed by Saskatchewan Environment

TABLE I-7b

Projected Future Water Uses in
the Poplar River Basin: Saskatchewan[a]
(acre feet)
(Including existing uses listed in Table I-1)

| | Municipal | | Domestic | | Irrigation Water Spreading | | Irrigation Full Service | | Reservoir Evaporation | | Industrial | | Wildlife | | Total Use By Subbasin | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 |
| West Poplar River Subbasin | 0 | 0 | 58 | 58 | 35 | 35 | 100 | 100 | 230 | 230 | 0 | 0 | 0 | 0 | 423 | 423 |
| Poplar River Subbasin | 0 | 333 | 173 | 173 | 0 | 0 | 73 | 73 | 0 | 3600 | 0 | 2541 | 150 | 150 | 396 | 6870 |
| East Poplar River Subbasin | 150 | 317 | 477 | 477 | 192 | 192 | 119 | 119 | 3600 | 3600 | 2180 | 2180 | 150 | 150 | 6868 | 7035 |
| Column Subtotals | 150 | 650 | 708 | 708 | 227 | 227 | 292 | 292 | 3830 | 7430 | 2180 | 4721 | 300 | 300 | 7687 | 14 328 |

(a) These estimates were developed by Saskatchewan Environment

TABLE I-8a

Total Projected Future Irrigation in Montana, Exclusive of the Fort Peck Indian Reservation (1985 and 2000)[a]

| | Waterspreading | | | | Sprinkling | | | | Flooding | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1985 | | 2000 | | 1985 | | 2000 | | 1985 | | 2000 | |
| | hectares | $dam^3$ req'd[b] | hectares | $dam^3$ req'd | hectares | $dam^3$ req'd | hectares | $dam^3$ req'd | hectares | $dam^3$ req'd | hectares | $dam^3$ req'd |
| West Poplar River Subbasin | 284 | 719 | 446 | 1133 | 168 | 1174 | 403 | 2820 | 57 | 430 | 124 | 936 |
| Poplar River Subbasin (middle fork) | 87 | 221 | 151 | 383 | 140 | 981 | 340 | 2383 | 138 | 1044 | 190 | 1444 |
| Poplar River Subbasin | 263 | 668 | 428 | 1088 | 154 | 1078 | 356 | 2496 | 344 | 2611 | 398 | 3018 |
| East Poplar River Subbasin | 462 | 1171 | 530 | 1344 | 0 | 0 | 0 | 0 | 38 | 291 | 91 | 692 |
| Column Subtotals | 1096 | 2779 | 1555 | 3948 | 462 | 3233 | 1099 | 7698 | 577 | 4376 | 803 | 6090 |

(a) These projections do not compare with the Task Force, figures. These estimates were developed by the Montana Department of Natural Resources and Conservation, 1978.

(b) dam req'd$^3$ - cubic decametres of water required.

TABLE I-8b

Total Projected Future Irrigation in Montana, Exclusive of the Fort Peck Indian Reservation (1985 and 2000)[a]

| | Waterspreading | | | | Sprinkling | | | | Flooding | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1985 | | 2000 | | 1985 | | 2000 | | 1985 | | 2000 | |
| | Acres | AF req'd[b] | Acres | AF req'd | Acres | AF req'd | Acres | AF req'd | Acres | AF req'd | Acres | AF req'd |
| West Poplar River Subbasin | 700 | 583 | 1102 | 919 | 414 | 952 | 994 | 2287 | 140 | 349 | 305 | 759 |
| Poplar River Subbasin (middle fork) | 215 | 179 | 373 | 311 | 346 | 796 | 840 | 1932 | 340 | 847 | 470 | 1171 |
| Poplar River Subbasin | 650 | 542 | 1057 | 882 | 380 | 874 | 880 | 2024 | 850 | 2118 | 983 | 2448 |
| East Poplar River Subbasin | 1140 | 950 | 1308 | 1090 | 0 | 0 | 0 | 0 | 95 | 236 | 225 | 561 |
| Column Subtotals | 2705 | 2254 | 3840 | 3202 | 1140 | 2622 | 2714 | 6243 | 1425 | 3550 | 1983 | 4939 |

(a) These projections do not compare with the Task Force, figures. These estimates were developed by the Montana Department of Natural Resources and Conservation, 1978.

(b) AF req'd - acre feet of water required.

## Future Domestic Uses

Domestic and rural household waste water is assumed to return negligible amounts of the basin's water system, as such wastes will be disposed of by jet spray or non-discharging lagoons.

The domestic use projections listed in Table I-7 are only slightly less than those projected by the Task Force, (i.e., 873 cubic decametres (708 acre feet), as opposed to 900 cubic decametres (730 acre feet). The 900 cubic decametres (730 acre feet) referred to in the Task Force Report included other Canadian tributaries. The amount distributed to each fork for future uses was determined using the same percentage distribution as that of the Task Force.

## Future Irrigation

Appendix C of the Task Force Report states that there are no firm plans for large scale irrigation development in Saskatchewan. A brief description is, however, given for areas where irrigation potential has been investigated.

Page 31 of the main Task Force Report projects a Saskatchewan use intention by 1985 of 271 cubic decametres (220 acre feet) per year for irrigation. This additional requirement over existing uses was assumed to consist of 23 cubic decametres (100 acre feet) for a specific project identified by the Task Force on the West Poplar River and another 148 cubic decametres (120 acre feet) divided over the basin.

## Future Industrial

Page 31 of the main Task Force Report projects Saskatchewan industrial use intentions by 1985 and additional possible future industrial use in excess of the water available under the apportionment recommendations. With the information available, it is not possible for the committee to priorize the industrial uses listed by the Task Force.

The committee has been advised through personal communications with Water Survey of Canada staff that it is physically feasible to construct a water storage reservoir on Goose Creek to store water from the Poplar River. Since there is water available to Saskatchewan on the Poplar River under the apportionment recommendations, it was assumed that water would be used by the year 2000 for evaporation from a large reservoir and for an unspecified industrial use.

### Future Wildlife

The Task Force Report, Appendix C, listed several locations where Ducks Unlimited (Canada) has identified potential water uses for wildlife. The Task Force, estimated 25 percent of these projects would be feasible with an estimated annual water use of 370 cubic decametres (300 acre feet). This amount was arbitrarily split between the Poplar River and East Poplar River and assigned under the 1985 column in Table I-1.

## Future Uses in Montana, Exclusive of the Reservation

### Municipal Use

Projections for the future use of municipal water by Scobey must be made with alternate possibilities in mind: (a) Scobey's population will continue to decline slightly, as it has for the past 15 years, or (b) potash mining and processing development will result in a significant increase in Scobey's population.

Scobey, like numerous small cities in Montana with a predominantly agricultural economic base, has experienced a population decline over the past 15 years. In the absence of industrial development near Scobey, a continued decline of slightly less than one percent per year to the year 2000 is projected by the Montana Alternative Simulation System (MASS). MASS is a computerized data file and model developed by the Montana Department of Community Affairs for the purpose of providing a consistent set of county-level employment and population projections, as well as a general framework for evaluating the impacts of industrial developments. The system was used to produce population projections for Daniels County, based on the two possibilities discussed above.

Assuming municipal water use remains at the 1975 level of use, or approximately 795 litres (210 gallons) per person per day, municipal water use could actually be reduced in the future. A population of 1310, as projected for 2000, would require 380 cubic decametres (308 acre feet) per year. But, Scobey residents used approximately 189 litres (50 gallons) of water per person per day more in 1975 than in 1970. Assuming that the requirement levels off at 946 litres (250 gallons) per person per day, a population of 1310 in the year 2000 would require approximately the same amount of water then as it requires under exisiting conditions, roughly 432 cubic decametres (350 acre feet) per year. The effect of Scobey's sewage lagoons on the water quality of the Poplar River has not been determined for boron and TDS.

The Farmers Potash Company of Montana has

applied for beneficial water use permits for the Poplar River basin and has initiated exploratory work toward the development of a potash mining and processing facility near Scobey. Should all state requirements be satisfied and the company choose to mine and process potash in the basin, the development would have an appreciable impact on Scobey's population and thus municipal water use. But, water rights applications, economic feasibility studies and facility siting applications would require considerable time. It is not likely, therefore, to materialize before 1985. Thus, its impact on Scobey's populuation would be greatest from 1990 to 1995; after which the expected population decline would begin again. The projected increase in municipal water use resulting from potash development would peak at an estimated 801 cubic decametres (650 acre feet) per year, assuming a liberal 946 litres (250 gallons) per person per day would be consumed. By the year 2000, the requirement would be reduced to approximately 740 cubic decametres (600 acre feet) per year (Montana Department of Natural Resources and Conservation, 1978).

As stated previously, Scobey's three wells are capable of supplying approximately 3407 litres (900 gallons) per minute. Sustained, this totals 4 905 878 litres (1 296 000 gallons) per day, or roughly 1788 cubic decametres (1450 acre feet) per year - more than twice the municipal water that would be required daily, even with a potash development.

### Domestic Uses

Projections of future use with respect to stockwatering and reservoir evaporation are based on a trend analysis. It is projected that approximately 35 000 head of cattle (Montana Department of Natural Resources and Conservation, 1978) will be raised in the area by the year 2000. Accordingly, the number of reservoirs is expected to increase sufficiently to satisfy stockwatering needs for this projected increase. It is assumed that; due to their location, eutrophication and other factors; the reservoirs now in existence will not be capable of satisfying the future requirement. Still, an increase of only 515 cubic decametres (418 acre feet) per year is projected for both stockwatering and evaporation, as compared to 1975.

### Future Irrigation

The Montana Department of Natural Resources and Conservation reconnaissance level land classification system categorizes lands according to their suitability for growing crops. Such considerations as soil chemistry, texture and depth, lay of the land and distance from a water source, as well as other factors, are used in the classification. Class 1 lands are best suited for growing crops, Class 6 lands are least suited and, generally, it is not feasible to consider Class 4, 5, or 6 lands as irrigable. A general survey of the lands not yet irrigated in the Montana portion of the basin, excluding the reservation, was carried out by that department. The following results were

obtained: (a) no Class 1 lands, (b) 23 976 hectares (59 200 acres) of Class 2 lands and (c) 94 770 hectares (234 000 acres) of Class 3 land remains.

In 1975, a total of 1548 hectares (3823 acres) was irrigated in the Montana portion of the basin, excluding the reservation, 759 hectares (1875 acres) by water spreading and 789 hectares (1948 acres) by gravity and pumping. The land available for irrigation is by no means the limiting factor when projecting future irrigation in this case. Rather, water availability and water quality will limit irrigation unless adequate groundwater sources can be found.

Water use for irrigation in the basin, including both water spreading and full service irrigation, increased sharply in the early 1960's and has continued to increase rather steadily to the present. It is reasonable to assume that until water quality and quantity limitations are reached, irrigation use could continue to increase at a rate that follows the trends of the past 15 years. However, the actual rate may be lower than the projected rate due to such factors as abandonment of existing systems and uncertainty regarding the impact of the power plant.

Table I-8 presents projected future irrigation acreage and use figures for Montana, excluding the reservation. Based on regression analysis of the number of acres irrigated by water spreading from 1960 through 1975, and by full service irrigation from 1961 through 1975, total area-wide acreage figures were projected for the years 1985 and 2000. Maps of the area were used to determine which Class 2 lands would most likely be irrigated in the future. It was assumed that 75 percent of the future full service irrigation would employ sprinklers. The regression analysis was carried out and the locations of future irrigation by subbasin were determined for the committee by the Technical Services Bureau of the Montana Department of Natural Resources and Conservation. The associated use requirement figures (volume requirement) were calculated by using the same assumptions as those in deriving the requirements for existing uses (Table I-4).

The projections for future irrigation are plausible only if a sufficient water supply will be available.

With respect to water availability for water spreading, it is reasonable to assume that the projected requirements could be met since water spreading systems trap the spring runoff of largely intermittent streams. This water might otherwise flow out of the basin at a time when water shortages do not occur in the basin. With respect to water availability for full service irrigation, as practised in this basin, a water supply is considered adequate if at least three applications of water are available in most growing seasons. The average number of applications during the period from 1931 through 1975, as determined by the Task Force, was 2.4 per season.

## TABLE I-9

Median Monthly Flow Figures for Selected Scenarios
at Three Study Points in the Poplar River Basin
(cubic hectometres per month)

Station 8 - Poplar River at the Fort Peck Indian Reservation Boundary

| | Scenarios | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 7 | 8 | 9 | 12 | 19 |
| May | 2.87 | 2.90 | 2.77 | 2.27 | 2.19 | 3.23 |
| June | 1.64 | 1.67 | 1.49 | 0.83 | 0.68 | 2.32 |
| July | 0.38 | 0.40 | 0.22 | 0.00 | 0.00 | 1.6 |
| August | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.88 |
| September | 0.21 | 0.23 | 0.14 | 0.00 | 0.00 | 0.58 |

Station 11 - West Poplar River Near Its Mouth

| | Scenarios | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 7 | 8 | 9 | 12 | 19 |
| May | 1.03 | 1.03 | 0.95 | 0.72 | 0.69 | 1.11 |
| June | 0.53 | 0.56 | 0.45 | 0.13 | 0.11 | 0.72 |
| July | 0.17 | 0.17 | 0.00 | 0.00 | 0.00 | 0.46 |
| August | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.27 |
| September | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.1 |

Station 12 - Poplar River Near Its Mouth

| | Scenarios | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 7 | 8 | 9 | 12 | 19 |
| May | 5.95 | 6.16 | 2.64 | 0.00 | 0.00 | 0.00 |
| June | 4.01 | 4.04 | 2.01 | 0.00 | 0.00 | 0.00 |
| July | 1.42 | 1.44 | 0.69 | 0.00 | 0.00 | 0.00 |
| August | 0.51 | 0.52 | 0.15 | 0.00 | 0.00 | 0.00 |
| September | 0.73 | 0.74 | 0.52 | 0.00 | 0.00 | 0.00 |

Given the water quality requirements developed by this Committee for existing and projected future full service irrigation, the Surface Water Quality Committee has presented summary listings of predicted stream flows at 12 study points, assuming various levels of water usage (see Attachment 1 of the report of the Surface Water Quality Committee). From these data, which are further summarized for the purposes of this report in Table I-9, the following conclusions can be drawn.

1. Under existing conditions (1975 level of use in both Saskatchewan and Montana), including the presence of Cookson Reservoir, but without a power plant operating, there is a sufficient amount of water available in all five months of the irrigation season, at least five years out of ten for all consumptive water uses in the basin.

2. Under conditions that would exist with two power units operating and the 1975 level of development in both Saskatchewan and Montana, it is predicted that there would still be a sufficient amount of water available in all five months of the irrigation season, at least five years out of ten for all consumptive water uses in the basin.

3. Under the conditions of the projected future levels (1985 and 2000) of irrigation in Montana, in conjunction with the operation of two power units in Saskatchewan and full apportionment, it is predicted that streams in the basin, or portions of them, would be depleted to zero flow. In many years, this could occur in all five months of the irrigation season.

The six scenarios selected represent a cross-section of the various levels of existing and projected future use conditions in the basin. Briefly they are:

a) Scenario 3 - 1975 level of development in Saskatchewan and Montana; Cookson Reservoir in place, but no power plant operating.

b) Scenario 7 - 1975 level of development in Saskatchewan and Montana; two power units operating.

c) Scenario 8 - 1985 level of development in Saskatchewan and Montana; two power units operating.

d) Scenario 9 - 1985 level of development in Saskatchewan; 2000 level of development in Montana; two power units operating.

e) Scenario 12 - 1985 level of development in Saskatchewan; 2000 level of development in Montana; two power units operating; assume full apportionment is exercised by Saskatchewan; a reservoir on the Poplar River.

f) Scenario 19 - 1975 level of development in Saskatchewan; no development in Montana north of the Fort Peck Indian Reservation; 2000 level of development on the reservation; two power units operating in Saskatchewan.

A more precise explanation of the assumptions in each scenario is presented in Section V, Predicted Water Quality, of the Report of the Surface Water Quality Committee.

A note of caution is in order. The amounts of water predicted to be available after satisfying the consumptive uses, according to the various scenarios, may or may not be adequate to protect instream values for aquatic use.

Industrial Use

Saskatchewan Power Corporation's power plant and ancillary facilities being constructed near Coronach, Saskatchewan represent the only specific non-agricultural industry currently identified in the Poplar River basin that requires water. However, the area possesses vast potash and lignite coal reserves. Both of these resources represent potential industrial development in the study area that would require the consumptive use of water.

Potash Reserves

The Farmers Potash Company has begun preliminary work toward development of a potash mining facility in the Poplar River basin. The company has submitted two applications to the Montana Department of Natural Resources and Conservation for beneficial water use permits. Both are proposals to construct reservoirs, but only one would be in the basin. If approved, it would be constructed on the East Poplar River near Scobey and would have a capacity of up to 8650 cubic decametres (7000 acre feet).

The proposed development would require a construction force of about 1500 workers over a period of 26 to 30 months. An estimated 200 persons would be employed during normal operations of the facility and it is assumed that Scobey would absorb the population impact. The increase in municipal water use demands that would result is considered in a previous section (Future Municipal Use).

However, the potential impacts of such a development on the quality of Poplar River basin waters are not known. Therefore, those impacts are neither discussed in this report, nor modelled by the Surface Water Quality Committee.

### Coal Reserves

Coal deposits in the study area have been described by the United States Bureau of Mines as generally non-strippable, due to an unfavorable ratio of overburden depth to depth of the coal seam and an extensive mantle of glacial till. As of 1975, the Montana Bureau of Mines and Geology had not made estimates of coal reserves in the study area.

## Future Uses on the Fort Peck Indian Reservation

The Sioux and Assiniboine tribes of the Fort Peck Indian Reservation have firm plans to construct a large storage reservoir on the lower Poplar River. It is to be used to irrigate 4050 hectares (10 000 acres) of presently undeveloped land by 1985 and an additional 4050 hectares (10 000 acres) by the year 2000. Additional lands may be developed after 2000. Soils classification indicates that there are over 40 500 hectares (100 000 acres) of irrigable land that can be serviced by the Poplar River. Currently the lands are intended to be seeded to alfalfa.

The dam for the proposed reservoir may have an adverse impact on the stream biota but the significance of this is not known at this time.

The lands to be irrigated lie primarily between the Poplar River and Big Muddy Creek drainages. Therefore, return flows would not affect the Poplar River basin. They will empty into intermittent tributaries of the Missouri River.

Table I-10 presents projections of future water use on the reservation. Domestic uses and uses associated with water spreading show no change over existing levels.

The method used in determining the future diversion requirements is as follows:

(1) Using the 1931 - 1974 climatological data, crop evapotranspiration rates were calculated for each month of the 1931 - 1975 period. The Modified Blaney-Criddle Method was used.

TABLE I-10a

Projected Future Uses in the Poplar River Basin:
Fort Peck Indian Reservation
(cubic decametres)

| | Domestic | | Irrigation | | | | Reservoir Evaporation | |
|---|---|---|---|---|---|---|---|---|
| | | | Waterspread | | Full Service | | | |
| | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 |
| West Poplar River Subbasin | 109 | 109 | 48 | 48 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 989 | 989 | 321 | 321 | 34 682 | 68 784 | 6071 | 6071 |
| Column Subtotals | 1098 | 890 | 369 | 369 | 34 682 | 68 784 | 6071 | 6071 |

TABLE I-10b

Projected Future Uses in the Poplar River Basin:
Fort Peck Indian Reservation
(acre feet)

| | Domestic | | Irrigation | | | | Reservoir Evaporation | |
|---|---|---|---|---|---|---|---|---|
| | | | Waterspread | | Full Service | | | |
| | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 | 1985 | 2000 |
| West Poplar River Subbasin | 88 | 88 | 39 | 39 | 0 | 0 | 0 | 0 |
| Poplar River Subbasin | 802 | 802 | 260 | 260 | 28 128 | 55 786 | 4924 | 4924 |
| Column Subtotals | 890 | 890 | 299 | 299 | 28 128 | 55 786 | 4924 | 4924 |

(2) The effective precipitation for each month was subtracted from the crop evapotranspiration rate to obtain the irrigation requirement for comsumptive use. The 44-year average was used as the crop consumptive use requirement.

(3) A 65% efficiency was used to determine the diversion requirement. This efficiency is based on concrete lined canals and sprinkler irrigation.

(4) The reservoir evaporation was determined using climatological data and calculated reservoir levels for the 1931-1974 period.

In accordance with the Winters Doctrine of Water Rights, the State of Montana recognizes that the Fort Peck Indian tribes have an unspecified quantity of Poplar River water reserved for present and future uses. The tribes have resolved that the full natural flow of the Poplar River is the measure of that right.

The Uses and Water Quality Objectives Committee has not made any decisions on the matter. The committee has requested an examination into the effects that alternative use options could have on the quality of the basin's water and on the recommended apportionment schedule. The results are delineated in the report by the Surface Water Quality Committee.

## Conclusions

Because of the highly variable supply of water in the basin, it is difficult to judge at what point projected levels of irrigation would become competitive with existing uses. Existing water shortages under current development, coupled with extensive development possibilities in Montana, clearly show that the amount of water available to Montana in most years may not fully satisfy the projected full service irrigation requirements. These constraints indicate that water storage may be necessary to satisfy projected requirements. This, in fact, is the solution at the present time in certain parts of the basin during low flow periods. During such periods, irrigation supplies are drawn from deep pools and illuvial deposits of Montana streams.

## Recommendations

Therefore, while the members of this international committee recognize that such decisions would generally be left to the discretion

of Montana, the Fort Peck Indian Tribes and the United States Government, it is recommended that provisions be made to reserve a portion of the average annual flow of each fork for the protection and maintenance of aquatic life.

# PART II

# WATER QUALITY OBJECTIVES

# PART II WATER QUALITY OBJECTIVES

## Introduction

This part of the report deals with the development of multiple-purpose water quality objectives for the basin. The objectives, as proposed, are applicable to all locations within the basin including the international boundary crossing points of the basin rivers and in the Fort Peck Indian Reservation.

The objectives, as recommended, represent scientific judgements based upon the best available information on chemical substances and/or physical materials and their concentration/effect relationship to biological or environmental receptors relevant to the waters of the basin. The judgements also included the best available information on present and future water uses; historical, prevailing and predicted water quality conditions supplied by the Surface Water Quality Committee; and the naturally occurring organisms using the waters of the basin as determined by the Biology Resources Committee.

In addition, the judgements took into consideration the apportioning of transboundary flows of the rivers of the basin based on the report of the Task Force, the terms and conditions of the Boundary Water Treaty 1909, and the water requirements of the Fort Peck Indian Reservation.

Because the multiple-purpose water quality objectives developed for this basin are based on the best available scientific and technical information and employing scientific judgements, they should not be used as absolute values of water quality but with considered judgement backed by an adequate monitoring program and with an understanding of their development as delineated in the various sections of this part of the report and in Annexes A to E to the report.

The water quality objectives for this basin were developed under the limitations of best available information, therefore they cannot be expected to ensure absolute protection for all water uses. However, if used objectively they will give an adequate degree of protective assurance for water users until better information becomes available.

This part of the report also contains a section on forecasts of impacts of present and future water uses on water quality in relation to developed water quality objectives for the basin. The section deals with comparisons of selected water quality objectives to predicted water quality caused by man's development and natural phenomena including the water quality parameters requiring mitigative measures due to the impact of SPC operations and water quality parameters where mitigation is

impossible or impractical.

A section is also included on methods for monitoring for compliance with water quality objectives to ensure compatibility and accuracy of field and laboratory results.

## FRAMEWORK PLAN FOR FORMULATING MULTIPURPOSE WATER QUALITY OBJECTIVES FOR THE POPLAR RIVER BASIN

1. Based on the identified present and reasonably foreseeable water uses for the basin, develop by parameter, water quality objectives for each reasonably foreseeable water use from the best available scientific information.

2. From these water quality use objectives, identify in parametric and/or descriptive terms the water quality requirements that will assure protection of the most sensitive water use identified. These requirements will be the multipurpose water use objectives for the basin waters.

3. From water quality data supplied by the Water Quality Committee, identify the natural past, prevailing, and predicted quality of the waters of the basin.

4. By a detailed assessment of natural past, prevailing and predicted water quality of the basin in relation to the multipurpose water quality use objectives, establish specific water quality objectives for the basin. The assessment must take into consideration the following points:

    (1) Should the prevailing and predicted quality of the basin waters meet or be better than the multipurpose water quality use objectives,

    (a) the multipurpose water quality use objectives can become the specific water quality objectives for the basin or

    (b) the multipurpose water quality use objectives can be upgraded to meet the prevailing and predicted quality of the basin water. The upgraded values become the specific water quality objectives for the basin.

    (2) Should the prevailing and predicted quality of the basin waters not meet the multipurpose water quality use objectives, the cause must be determined and,

    (a) if the cause can be rectified by source treatment or source control, the multipurpose water quality use objectives can become the specific water quality ob-

jectives for the basin.

(b) if the cause is natural or inputs from diffused sources which cannot be amply rectified, adjustment will have to be made to the multipurpose water quality use objectives to comply with the prevailing and predicted quality of the water in the basin or restrictions on water use within the basin will be required.

When the cause of exceeding one or a number of the multipurpose water quality use objectives is natural or inputs from diffused sources, and when controls are not feasible or practicable, the final choice must be based on the best choice of objectives that are deemed to support the optimum use of waters in the basin.

## WATER QUALITY USE OBJECTIVES FOR IDENTIFIED WATER USES

### Introduction

Poplar River waters, in a basin-wide sense, should not contain organisms, physical materials or chemical substances at levels that are deleterious to present and reasonably foreseeable uses. To meet this goal, some basic level of quality must be maintained throughout this waterway.

This basic level of water quality was derived by making use of best available scientific information for each identified water use and of scientific judgement and experience. However, it is important to be aware there are limitations in the scientific data base that make it less than ideal for determining the exposure-effect relationships between toxicants and receptors. This is so for any single toxicant and still more so for combinations of toxicants (antagonism, synergism, addition). Given these limitations, judgemental discretion dictated that a substantial safety factor be employed to ensure the protection of the use. This was accomplished by (1) the use of application factors to estimate the safe concentration of toxicants or (2) setting the requirements for the total concentration of toxicants.

The scientific bases for formulating the objectives for each of the water uses identified for the Poplar River Basin, as presented in this section of the report, can be found in Annexes A through D.

### Municipal and Domestic Potable Water Supply

The requirements for raw water quality for municipal and domestic water supply are intended to ensure that the water will be potable with the treatment process coagulation, sedimentation, filtration and disinfection.

The requirements should be regarded as guides in the control of health hazards and not as fine lines between safe and dangerous concentrations. The degree and length of time by which the values set out in Table II-1 can be exceeded without injury to health is not generally known. The requirements, however, can be considered a minimum target towards which efforts at upgrading the quality should be directed.

Toxic substances are known to be associated with suspended materials in raw surface waters and may be removed to some extent by

treatment processes. The degree of removal of these toxic substances is not generally known. Therefore, in the interest of safety, it has been assumed that no removal of these toxic substances will result from the treatment process.

Municipal and domestic water uses include water needed for human consumption, household use, dairy production, livestock and garden irrigation.

TABLE II-1

Water Quality Requirements For Municipal and Domestic Uses

| Parametre | | Not to Exceed Limit | Referenced Annex |
|---|---|---|---|
| Chemcial Characteristics | | | |
| Arsenic, total | mg/L | 0.05 | A |
| Cadmium, total | mg/L | 0.01 | A |
| Chromium, total | mg/L | 0.05 | A |
| Copper, total | mg/L | 1.0 | A |
| Fluoride, total | mg/L | 1.5 | A |
| Iron, total | mg/L | 0.3 | A |
| Lead, total | mg/L | 0.05 | A |
| Manganese, total | mg/L | 0.05 | A |
| Mercury, dissolved | mg/L | 0.002 | A |
| Nitrate (as N) | mg/L | 10 | A |
| Sulphate | mg/L | 800 | A |
| Microbiological Characteristics | | | |
| Coliforms, total | Orgs/100 ml. | G.M.* 5000 | A |
| | | Max. 20 000 | A |
| Coliforms, fecal | Orgs/100 ml. | G.M. 1000 | A |
| | | Max. 2000 | |

*G.M. - Geometric means

## Irrigation, Stockwatering and General Agricultural Use

Agriculture in this river basin depends upon the quality of the water to achieve the fullest production of alfalfa, wheat, barley and livestock to satisfy general farmstead needs. The quality of the water is important to agriculture, not only in determining the productivity of plants and animals, but also as it affects the health and welfare of the human farm population.

Irrigation is one of the largest consumers of water in this basin. The differences in crop sensitivity to salinity and toxic substances necessitate the need to evaluate the water quality for this use. Polluted waters are detrimental to animal health and to the safety and value of agricultural products. Good quality water is also important to the health and comfort of rural families needing water for drinking, food preparation, bathing, and laundering.

Water quality requirements relate in turn to problems of pollution posed by run-off and by industrial and agricultural wastes. Naturally occurring constituents present in surface and groundwaters can also adversely affect agricultural uses of water. Among these substances are suspended solids, dissolved organic and inorganic substances and living organisms.

The task of evaluating the scientific data base and developing water quality objectives was complicated by the need to consider numerous complex interactions. Water quality requirements for irrigation must consider crop responses to climatic and soil factors and their interrelationships with water. Similarly, livestock drinking water quality requirements must consider the quantity of water consumed, and the animals' sex, size, age and diet. Due to these complex interactions, the basis of the requirements set out in this section were guided considerably by expert judgement.

### Irrigation

Plants can be adversely affected directly by either the development of high osmotic conditions in the plant substrate or by the presence of a phytotoxic constituent in the water. The effects of undesirable constituents may suppress growth, reduce seed development and impair the marketable quality of the product. In addition, elements in irrigation water may accumulate in crops to levels that can be harmful to animals and humans.

Plant growth may be affected indirectly through the influence of water quality on soil. High sodium waters can cause dispersion of the clay fraction in soils resulting in surface crust formations that deter seed germination and emergence. Highly saline waters tend to flocculate soils resulting in relatively high infiltration rates, as well as affect the osmotic pressure of the soil solution. The effects of

salinity, or total dissolved solids, is one of the most important water quality considerations. High soil salinity has been known to create physiological drought conditions.

Since the prevailing water quality of this river system during the irrigation season contains appreciable total dissolved solids (ranging in average monthly values between 700 and 1000 mg/L), the water quality requirement set out in Table II-2 required considerable expert judgement in their formulation.

TABLE II-2

Water Quality Requirements for Irrigation

| Parameter | Long-Term Limit | Short-Term Limit | Referenced Annex |
|---|---|---|---|
| Chemical Characteristics | | | |
| Boron, total mg/L | 5.0 (10 year) | 8.0 (3 consec. mos.) | C |
| Chloride | * | * | C |
| Sodium Adsorption Ratio (SAR) | 10 | * | C |
| Sodium, dissolved | * | * | * |
| Total Dissolved Solids (TDS) mg/L | 1000 (10 year) | 1500 (3 consec. mos.) | C |

* Decision that no requirements are necessary at this time.

## Stockwatering (including wildlife ungulates)

Domestic animals represent an important segment of agriculture in this river basin. Like man and other forms of life, they are affected by pollutants in water. Concentrations of nutrients and toxic substances in water affect the animal on the basis of the total amount consumed. All the mineral elements essential as dietary nutrients occur to some extent in water. However, if they occur in water in excess quantities physiological damage to the animals can occur. The water quality requirements given in Table II-3 are in-

tended to ensure that domestic animals and wildlife ungulates are not harmed through daily consumption of Poplar Basin waters.

TABLE II-3

Water Quality Requirements for Stockwatering (Including Wildlife Ungulates)

| Parameter | | Not to Exceed Limit | Referenced Annex |
|---|---|---|---|
| Chemical Characteristics | | | |
| Copper, total | | * | C |
| Cobalt, total | | * | C |
| Molybdenum, total | | * | C |
| Selenium, total | | * | C |
| Sulfate | mg/L | 1000 | C |
| Total Dissolved Solids (TDS) | mg/L | 3000 | C |

* Decision that no requirements are necessary at this time due to insignificant quantities presently in the water.

## Domestic and Other Farmstead Uses

Water to meet the needs of rural families for drinking, food preparation, bathing, and laundering and for dairy products should meet the standards for drinking water quality.

## Maintenance of Indigenous Biota

The biota of the Poplar River's aquatic ecosystem is the result of evolutionary processes in the course of which a balance has been established among various kinds of organisms and between such organisms and the environment. Minor changes in their environment, especially if such changes are rapid, can upset the ecological balance and endanger one or more species.

Man's use of water has often degraded water quality. Water pollutants can alter natural conditions by reducing dissolved oxygen levels, by changing the temperature, or by direct toxic action that can be lethal or, more subtly, can effect the behaviour, reproduction, and physiology of the organisms. A substance may not directly affect

## TABLE II-4

Water Quality Requirements
For Indigenous Biota

| Parameter | | Not to Exceed Limit | Referenced Annex |
|---|---|---|---|
| **Chemical Characteristics** | | | |
| Aluminum, dissolved | mg/L | 0.1 | B |
| Ammonia ($NH_3$), free | mg/L | 0.02 | B |
| Arsenic, total | mg/L | 0.1 | B |
| Cadmium, total | mg/L | 0.0012 | B |
| Chromium, total | mg/L | 0.1 | B |
| Copper, dissolved | mg/L | 0.005 | B |
| Iron, dissolved | mg/L | 0.6 | B |
| Lead, total | mg/L | 0.03 | B |
| Mercury, dissolved | mg/L | 0.0002 | B |
| Mercury, fish (wet wt., whole fish) | mg/Kg | 0.5 | B |
| Nitrates (N) | mg/L | 10% above natural | B |
| Oxygen, dissolved | mg/L | Footnote[1] | B |
| Phosphates (P) | mg/L | 10% above natural | B |
| pH | mg/L | 6.5 - 9.0 | B |
| Total Dissolved Solids (TDS) | mg/L | 2500 | B |
| Zinc, total | mg/L | 0.03 | B |
| **Physical Characteristics** | | | |
| Temperature | $^{o}C$ | Footnote[2] | B |
| Turbidity | N.T.U. | ±20% and footnote[3] | B |

Footnotes

[1] Greater than 5 mg/L between April 10 and May 15; greater than 4 mg/L during remainder of year.

[2] Water temperature from April 10 to May 15 should not be increased above natural. The maximum water temperature shall not be caused to exceed 30$^{o}$C.

[3] Turbidity shall not be caused to deviate more than ±20% of historic values based on correlations of historical stream flow vs turbidity measurements.

a species; however, it may endanger its continued existence by eliminating essential sources of food and metabolites. In addition, conditions permitting the survival of a given organism at one stage of its life may be intolerable at another stage.

The section evaluates the scientific data base and proposes water quality requirements that reflect scientific understanding of the relationships between the aquatic organisms of this river system and their environment.

The aquatic organisms which were used in determining the water quality requirements, Table II-4, were as follows:

| Species | Common Name |
|---|---|
| *Stizostedion vitreum* | Walleye |
| *Pimephales promelas* | Fathead Minnow |
| *Nitzschia palea* | Diatom |
| *Gammarus sp* | Crustaceans |
| *Gammarus minus*[1] | |
| *Daphnia magna* | |

[1] Does not occur in Poplar River basin.

## Contact Sports and Other Recreational and Aesthetic Considerations

The importance of suspended material composition and concentration to recreational and aesthetic values of surface waters relates to its effects on the clarity, light penetration, temperature, and dissolved constituents; the adsorption of toxic substances; and the composition, distribution and rate of sedimentation of materials. These not only affect recreational and aesthetic values directly, but they control or limit biological productivity and the aquatic life the water will sustain for the enjoyment of people.

## General Recreation and Contact Sports

Public Health Officials are concerned about the role of sewage-contaminated waters in the transmission of infectious disease. Contaminated water may transmit infectious agents; however, the concensus among those who have studied the relationship between water quality and bathers' illnesses appears to be that scientific proof of a direct relationship is lacking.

As no significant discharges of domestic wastes directly to the surface waters of the Poplar waterway are anticipated in the reasonably foreseeable future, the water quality objectives for this use are as set out in Table II-5.

### TABLE II-5

Water Quality Requirements
For Primary Contact Recreational Use

| Parameter | | Not to Exceed Limit | Referenced Index |
|---|---|---|---|
| Chemical Characteristics | | | |
| pH | Units | 6.5 to no more than 0.5 units greater than normal. | D |
| Microbiological Characteristics | | | |
| Coliforms, total<br>Coliforms, fecal | | No limits set due to lack of evidence of significant risk. | D |

## Aesthetic Considerations

Aesthetic is defined as appreciative of, responsive to, or zealous about the beautiful. As aesthetics relate to this basin, attention will be focused on the water in natural and man-made environments and the extent to which the beauty of the water can be preserved or enhanced by the establishment of water quality requirements.

The perceptions of beauty are individualistic. However, there is an apparent sameness in the human response to the beauties of water. Aesthetically pleasing waters add to the quality of human experience. Water can be pleasant to look upon, to walk or rest beside, or simply to meditate on.

Unfortunately, one of the greatest unkowns is the value of aethetics to people. It is because of this unknown value that aesthetically pleasing waters can only be described in descriptive terms. Thus, the water quality requirements for aesthetically pleasing water for this basin are by necessity descriptive.

The surface waters of this basin will be aesthetically pleasing if they are free of substances attributable to human activity as follows:

a. substances that will settle to form putrescent or otherwise objectionable sludge deposits; or will adversely affect aquatic life or waterfowl;

b. floating debris, oil, scum, and immiscible substances;

c. materials and heat that alone or in combination with other materials will produce colour, odour, taste, or other undesirable conditions;

d. nutrients in amounts that create undesirable aquatic plants.

## Industrial Water Supply

The present and reasonably foreseeable industrial activities in the basin are mainly agriculture and thermal electric power generation. Agricultural water needs are considered in Annex B. For steam generation and cooling uses, the water can be treated to achieve any specific requirement for steam generation as a part of plant operation: once-through cooling waters are generally used unaltered except for screening to remove debris and chlorinated for control of biological

organisms.

There is a wide range of chemical and physical changes that can take place in the water during steam generation and cooling processes. Such a variety of water treatment and conditioning methods exist that quality requirements for this use can have only very limiting practical significance. Therefore, water quality requirements for this use were not considered.

## POPLAR RIVER MULTIPURPOSE WATER QUALITY OBJECTIVES:

## BASIN INCLUDING INTERNATIONAL BORDER CROSSINGS

### Introduction

The multipurpose water quality objectives delineated in this section, if adhered to, will produce a water quality in the Poplar River system that will protect the life systems the waters support and man's use of the waters as described in this report.

These objectives were developed following closely the concepts of the Framework Plan for Formulating Multipurpose Water Quality Objectives for the Basin, outlined in a previous section, and by applying the following water quality principles. The objectives must:

1) define a water quality to protect downstream uses;

2) include ecological requirements, as well as the requirements for man's consumption and use; and,

3) be specific enough to permit an assessment of probable impacts of development.

Because a number of values presented relied heavily on expert judgement, especially the values relating to agricultural irrigation, they should be used conservatively until more information is available on exposure-effect relationships. It is essential that all of the objectives developed for this river basin be used coupled with adequate monitoring and surveillance programs to ascertain their degree of effectiveness in protecting the defined water uses of this basin.

### Defined Water Uses of the Poplar River Basin

The water uses for the Poplar River Basin are defined as:

1) municipal and domestic potable water supply,

2) irrigation, stockwatering and general agricultural use,

3) maintenance of indigenous biota,

4) contact sports and other recreational and aesthetic considerations, and

5) industrial water supply

## Multipurpose Water Quality Objectives

The objectives that follow are presented by parameter in both numerical and descriptive terms on the basis of the most sensitive of the multipurpose water uses for the basin. A brief explanation of the source of the objective accompanies each description.

In developing these objectives, if the natural water quality for a particular parameter exceeded the scientifically based limit and it was ascertained that the limit could be decreased to an acceptable level through economical treatment measures before its use, the limit was set at the natural water quality level.

In addition, the objectives were developed while keeping in mind at all times their accumulative effect on any impoundments that may be put in place on the Poplar River in the downstream portion of the basin.

The quality requirements specific to each water use are presented, in detail, in Annexes A through D. These annexes should be referred to if detailed information is required on the scientific bases for formulating the objectives.

### Aluminum

Recommendation: concentrations of dissolved aluminum in water samples should not exceed 0.1 milligrams per litre to protect the most sensitive water use, aquatic life.

Rationale: background aluminum data for the waters of the basin are sparse. The recommended objective, therefore, had to be based on the scientific requirements for the protection of the type of aquatic life present in the basin.

### Ammonia

Recommendation: concentrations of un-ionized ammonia ($NH_3$) should not exceed 0.02 milligrams per litre to protect the most sensitive use, aquatic life.

Rationale: concentrations of un-ionized ammonia in water is dependent upon temperature, alkalinity and pH. However, the alkalinity present in Poplar River waters will have an insignificant effect on limiting un-ionized ammonia.

The conditions under which the objective is limiting is given in the following table.

Percent Un-ionized Ammonia in Aqueous Ammonia Solution

| TEMPERATURE (°C) | pH VALUE 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.013 | 0.04 | 0.13 | 0.39 | 1.2 | 3.8 | 11. | 28. | 56. |
| 10 | 0.019 | 0.059 | 0.19 | 0.59 | 1.8 | 5.6 | 16. | 37. | 65. |
| 15 | 0.027 | 0.087 | 0.27 | 0.86 | 2.7 | 8.0 | 22. | 46. | 73. |
| 20 | 0.04 | 0.13 | 0.4 | 1.2 | 3.8 | 11. | 28. | 46. | 80. |
| 25 | 0.057 | 0.18 | 0.57 | 1.8 | 5.4 | 15. | 36. | 64. | 85. |
| 30 | 0.081 | 0.25 | 0.8 | 2.5 | 7.5 | 20. | 45. | 72. | 89. |

Conditions under which the objective for total ammonia is limiting.

Conditions under which the objective for un-ionized ammonia is limiting.

Thurston, R.V., et al., 1974. Aqueous ammonia equilbrium calculations. Fisheries Bioassay Laboratory Technical Report No. 74-1, Montana State University, Bozeman, 18p.

## Boron

Recommendation: concentrations of total boron in water samples should meet the following requirements:

(1) the long-term (10-year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 5.0 milligrams per litre, and

(2) the short-term (any 3 consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 8.0 milligrams per litre,

to protect the most sensitive use, irrigation of agricultural crops.

Rationale: boron impairment to irrigated crop production is dependent upon the crop grown, amount of water applied, previous accumulation and soil type. Alfalfa is tolerant to boron levels in the irrigation

water up to 15 mg/L. The most sensitive crop grown under irrigation in the basin is barley. It is estimated that boron levels in the irrigation water will reduce barley yields as follows.

| Boron Concentration | Barley Yield Reduction |
|---|---|
| 1.5 mg/L | 8% |
| 3.0 mg/L | 15% |
| 5.0 mg/L | 25% |
| 8.0 mg/L | 40% |

Alfalfa is the principal crop irrigated and its production will not be impaired at a level of 5.0 mg/L. The recommended level will not completely protect irrigated barley production; however, the amount of irrigated barley represents only 10 percent of the total full service irrigation in the Montana portion of the basin, including the Fort Peck Indian Reservation. A level of 5.0 mg/L will result in a maximum barley yield reduction of about 25 percent in those areas affected by the operation of the power plant. However, most of the irrigated barley is grown in the upper Poplar River subbasin (middle fork) and in the West Poplar River subbasin and will not be affected by the planned power plant operations.

Therefore, the recommended objective of 5.0 mg/L will probably not protect all identified present uses, but the importance of the non-protected use, irrigated barley, is considered to be small in relation to the total amount of irrigation in the basin.

The estimated yield loss values of barley due to boron levels of 3.0, 4.0, 5.0, 8.0 mg/L in the East Poplar River at the international boundary are fully discussed under the mitigation section of this report.

## Cadmium

Recommendation: concentrations of total cadmium in water samples should not exceed 0.0012 milligrams per litre to protect the most sensitive use, aquatic life.

Rationale: background water quality data show that the basin waters approach 0.001 mg/L of cadmium. Ground waters which make up a significant portion of the flow in the East Poplar River just north of the international border show cadmium concentration slightly in excess of the recommended objective during various periods of the year.

## Chromium

Recommendation: concentrations of total chromium in water samples should not exceed 0.05 milligrams per litre to protect the most sensitive use, domestic water supply.

Rationale: background water quality data show the basin waters to have a yearly mean value of 0.03 mg/L. The probability of the waters of the basin exceeding the recommended value is slight.

## Copper

Recommendation: concentrations of dissolved copper in water samples should not exceed 0.005 milligrams per litre to protect the most sensitive use, aquatic life. Concentrations of total copper in water samples should not exceed 1.0 milligrams per litre to protect the most sensitive use, domestic water supply.

Rationale: copper in its ionized state is the most toxic form of copper to aquatic life. However, copper in this form is difficult to determine with present monitoring techniques. Dissolved copper concentrations are thus recommended. The recommended value was formulated to take into account all dissolved forms of copper present in the basin waters and will, therefore, provide adequate protection for aquatic life. There was insufficient data to determine the natural levels of dissolved copper in the waters of the basin.

The mean annual values for total copper in the waters of the basin are 0.01 mg/L. The recommended objective for total copper was formulated to ensure adequate protection for the consumers of the basin's waters.

## Fluoride

Recommendation: concentrations of total fluoride in water samples should not exceed 1.5 milligrams per litre to protect raw waters for public water supply, the most sensitive use.

Rationale: fluoride in water can be detrimental to animal life, including man, at levels greater than 2.0 mg/L. At these levels it can cause mottling of teeth and extremely high intakes can cause skeletal fluorosis. On the other hand, fluoride in water at concentrations between 1.0 and 1.5 mg/L can be beneficial in preventing dental caries. Fluoride is often added to finished water supplies to prevent dental caries in children. The concentration added is dependent upon the quantity of water consumed which, in turn is dependent upon the climatic conditions. In the cold continental climate characteristic of the Poplar River Basin, the recommended objective is appropriate for the prevention of dental caries in children.

## Iron and Manganese

Recommendation: limits of iron and manganese are not considered necessary to protect public water supply, the most sensitive use.

Rationale: the highest recorded mean annual values (6 years of records) for iron and manganese in the waters of the Poplar River Basin were 1.2 and 0.1 mg/L, respectively. The highest recorded values, during this period, were 11 mg/L for iron and 0.4 mg/L for manganese. These values are predicted to decrease downstream where most of the public water supply occurs. Foreseeable developments in the basin are not expected to significantly increase the levels of these constituents in the water. Iron and manganese levels in water can be reduced to acceptable drinking and aesthetic quality by relatively simple and economic treatment measures.

## Lead

Recommendation: concentrations of total lead in water samples should not exceed 0.03 milligrams per litre to protect the most sensitive use, aquatic life.

Rationale: The mean annual values of total lead in Poplar River waters are approximately 0.02 mg/L. The recommended objective is the concentration causing 16 percent reproductive impairment to *Daphnia magna* and will, therefore, protect aquatic life.

## Mercury

Recommendation: concentrations of dissolved mercury in water samples should not exceed 0.0002 milligrams per litre to protect the most sensitive use, aquatic life. Concentrations of total mercury in whole fish should not exceed 0.5 milligrams per kilogram (wet-weight basis) for the protection of fish-consuming birds and humans.

Note: U.S. Standards for human consumption is 1.0 mg/kg (fresh-weight) for the protection of humans.

Rationale: the mean annual levels of mercury in Poplar River waters are approximately 0.00005 mg/L. The biologically significant form of mercury is methylmercury. However, methylmercury is assimilated by aquatic organisms as fast as it is produced, which makes it impossible to detect by the analysis of water samples. Since fish concentrate methylmercury preferentially over other forms of mercury, and since they excrete it very slowly, they provide a good indicator of the mercury levels in water.

Present administrative guidelines for fish for human consumption promulgated by the Canadian Food and Drug Directorate is 0.5 mg/kg and by the U.S. Food and Drug Administration 1.0 mg/kg total mercury in edible portions of fish.

## Nitrate

Recommendation: concentrations of nitrate-nitrogen in water samples should not exceed 10 milligrams per litre to protect raw water for public water supply, the most sensitive use.

Rationale: nitrates are known to produce irritation of the mucous membrane of the stomach and diuresis accompanied by irritation of the mucous membrane of the uninary bladder. The recommended level is based on the relationship established between this chemical and the possible occurrence of infantile methemoglobinemia. Infantile methemoglobinemia, a disease characterized by specific blood changes and cyanosis, had been related to high nitrate-nitrogen content in water used in preparing infant formulas.

The recommended objective is not meant to control eutrophication. Although there is an eutrophication problem in the basin, there is insufficient data to determine that control of nitrogen input to the water would result in any substantial reduction in algal populations.

## Oxygen

Recommendation: dissolved oxygen concentrations should not be less than 5.0 milligrams per litre during the critical spawning period (April 10 through May 15), and not less than 4.0 milligrams per litre during the remainder of the year (May 16 through April 9) for the protection of aquatic life, the most sensitive use.

In areas where historic concentrations are periodically lower than 4.0 milligrams per litre, there should be no activity permitted which will further reduce dissolved oxygen concentrations.

Rationale: dissolved oxygen is a critical constituent of water for the continued healthy functioning of aquatic organisms. Inadequate dissolved oxygen in surface water may contribute to an unfavourable environment for fish and other aquatic life. The absence of dissolved oxygen may degrade the aesthetic quality of waters by giving rise to the malodorous products of anaerobic decomposition.

A value of not less than 5.0 mg/L is intended to protect the fish species present in the basin's waters during the critical egg hatching and larval development period. A value of not less than 4.0 mg/L is intended to protect fish during the remainder of the year. Historical data show that under natural conditions the dissolved oxygen levels in the basin's waters can fall below 4.0 mg/L during the winter months when flows are minimal. The second part of the recommended objective is to prevent further aggravation of the problem.

## pH

Recommendation: values of pH in the waters should be greater than 6.5 units and no activity should cause the pH to be raised more than 0.5 units from the natural to protect body contact recreational activities, the most sensitive use.

Rationale: eye irritation will be minimized for most bathers and recreational enjoyment will be enhanced if the waters have a pH range of 6.5 to 9.0. The waters of the basin during the bathing period range in pH from a low of 7.9 to a high of 9.0. By maintaining these waters at natural pH values or by not allowing any activities to cause them to decrease to pH values less than 6.5 in increments of 0.5 pH units, adequate protection will be provided for all recreational uses.

## Sulfate

Recommendation: concentrations of sulfates in waters should not exceed 800 milligrams per litre to protect raw water for public water supply, the most sensitive use.

Rationale: the direct physiological effects of sulfates on humans is catharsis. High concentrations of sulfates may contribute to objectionable taste in water. Waters with sulfate concentration less than 800 mg/L are useable for drinking water without causing gastro-intestinal irritation and catharsis except in the case of transients who are not used to water with high sulfate concentrations. The waters of the basin contain sulfate concentrations ranging from a low of 12 mg/L to a high of 660 mg/L.

## Temperature

Recommendation: the temperature of the water should not be caused to exceed natural during the critical spawning period (April 10 through May 15) nor should the maximum temperature be caused to exceed 30 degrees centigrade for the remainder of the year (May 16 through April 9) to protect aquatic life, the most sensitive use.

Rationale: living organisms respond to temperature extremes or to temperature changes caused by transfer of heat. Aquatic organisms have upper and lower tolerance limits, optimum temperatures for growth, and temperature limitations for migration, spawning and egg incumbation. The composition of the aquatic communities of the waterways of this basin depends largely on the temperature characteristics of the water environment of the basin. Natural diurnal and seasonal cycles must be maintained, annual spring and fall changes in temperature must be gradual, and large unnatural day-to-day fluctuations in temperature should be avoided.

## Total Dissolved Solids

Recommendation: concentrations of total dissolved solids in water samples should meet the following requirements:

1) the long-term (10-year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1000 milligrams per litre, and

2) the short-term (any 3-consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1500 milligrams per litre.

to protect the most sensitive use, irrigation of agricultural crops.

Rationale: there is a large disparity in professional opinion and judgement regarding the level of total dissolved solids (TDS) which noticeably impairs crop production. Recommended acceptable levels range from 500 mg/L to 5000 mg/L.

Crop impairment due to elevated TDS levels is highly dependent on such factors as the amount of water applied, soil types, soil treatment, type of crops grown, and the sodium adsorption ratio (SAR).

Irrigation is currently being practiced successfully in western North America using waters of significantly higher TDS concentrations than the recommended objective. There are also areas in Northern Montana where irrigation operations utilizing waters with TDS concentrations less than the recommended objectives have failed.

A TDS objective for the non-irrigation period (October 1 through April 30) has not been recommended. Historical data show that during this period the TDS concentrations in these waters have not reached levels that would be harmful to other uses. During the low flow period in the basin (November through February), historical data show that the discharge volumes are too small for the higher TDS waters present to substantially impact the water quality in any proposed downstream irrigation water storage reservoirs. During the spring run-off period (March and April), the higher discharge volumes would substantially decrease TDS concentrations in reservoirs.

Therefore, the objective for TDS as proposed should provide adequate protection for the irrigation water needs of the basin, if water is applied in recommended amounts.

The effects of TDS concentrations in irrigation waters on alfalfa yields are fully discussed under the mitigation section of this report.

## Zinc

Recommendation: concentrations of total zinc in water samples should not exceed 0.03 milligrams per litre to protect aquatic life, the most sensitive use.

Rationale: in general, fish are more sensitive to zinc than other aquatic organisms. The recommended objective was set to protect the fish species that inhabit the waters of this basin. Available data show that the objective is approached occasionally in the waters of the basin.

## Sodium Adsorption Ratio (SAR)

Recommendation: the sodium adsorption ratio in water samples should not exceed a value of 10 to protect the most sensitive water use, irrigation of agricultural crops.

Rationale: sodium in irrigation water can become a problem in soil solution as a component of total alkalinity which can increase the osmotic concentration causing injury to plants. Sodium can also cause problems in soils, mainly in soil structure, infiltration and permeability ratio. When the amount of adsorbed sodium exceeds 10 to 15 percent of the total cations on the exchange complex of a soil, the soil clays become dispersed and slowly permeable, unless a high concentration of total salts causes flocculation.

The adsorption of sodium from a given irrigation water is a function of the proportion of sodium to calcium and magnesium in that water. An estimation of the degree to which sodium will be adsorbed by a soil from a given water when brought into equilibrium with it is generally done by the calculation of the SAR.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

For general crops, a limit of 8 to 18 is generally considered within a useable range, although this depends to some degree on the type of clay mineral, electrolyte concentration in the water, and other variables. For the crops grown in the Poplar River Basin, the type of soil in the basin under irrigation and the chemical characteristics of the basin's waters, a SAR value of 10 was determined to be a safe value. The present SAR values of the basin's waters range from a low of 2 to a high of 6.

A nomogram for determining the SAR values of irrigation water is available in Handbook 60, Diagnosis and Improvement of Saline and Alkali Soils published by the U.S. Department of Agriculture, Salinity Laboratory, 1954. Available from the Government Printing Office, Washington, D.C. 20402.

## Coliform Organisms

Recommendation:

1) the geometric mean of fecal coliform and total coliform densities in raw water supplies for domestic use should not exceed 1000 per 100 millilitres and 5000 per 100 millilitres, respectively.

2) the maximum densities of fecal coliforms and total coliforms in raw water supplies for domestic use should not exceed 2000 per 100 millilitres and 20 000 per 100 millilitres, respectively.

3) waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses which may produce enteric disorders, infections of the eye, nose, throat or skin, or other human diseases and infections.

Rationale: bacteria of the coliform group are considered to be the primary indicators of sanitary quality in water. Total coliform bacteria are associated with feces of warm-blooded animals and with soil. In using total coliform measurements in determining sanitary quality, it should be realized that such data are subject to a wide range of density fluctuations of doubtful sanitary significance. Fecal coliform bacteria are more indicative of the intestinal tract of warm-blooded animals than are total coliform bacteria.

Pollution of the aquatic environment by excreta of warm-blooded animals creates public health problems for man and animals and potential disease problems for aquatic life. It is known that enteric microbial pathogens may inhabit the gut of most warm-blooded animals and are shed in feces. Thus, the number of fecal organisms present indicates the possibility of recent contamination of water by the feces of warm-blooded animals.

## FORECAST OF THE IMPACT OF PRESENT AND FUTURE WATER USES ON WATER QUALITY IN RELATION TO PROPOSED WATER QUALITY OBJECTIVES

This section of the report presents, in the best judgement of the Committee, forecasts of the effects of present and future water uses on the quality of the water in the basin. Special emphasis is placed on the effects of the 600 megawatt power plant under development on the East Poplar River on the downstream quality of the waters of the Poplar River. In addition, consideration is given to the effects of water quantity apportionment on the water quality of the basin and the effects of present and future water use, including the power plant, on the proposed irrigation project for the Fort Peck Indian Reservation.

### Comparison of Selected Predicted Water Quality Parameters with the Proposed Water Quality Objectives

Only those water quality parameters that are expected to be significantly affected by present and future water uses in the basin are discussed here. They are total dissolved solids, boron, sulfates, and sodium adsorption ratio. The other parameters for which water quality objectives were developed do not show significant change due to present and future water uses. However, they do show values that are approaching the objective, and, therefore, should be monitored at least yearly.

In the following comparative analyses, the parametric values used were supplied by the Surface Water Quality Committee using its predictive model. The validity of the model has not been questioned by this Committee in utilizing the information. This Committee simply used the information from the model, as directed by the International Poplar River Water Quality Board.

In making the following comparison, it must be fully appreciated that the predicted values include periods of prolonged drought, such as the early 1930's and late 1950's and it should be kept in mind that of the total volume of water discharged from the basin into the Missouri River, approximately 28 percent originates in Canada and 72 percent in the United States.

#### Total Dissolved Solids (TDS)

The predicted historical mean monthly flow-weighted values for TDS, based on 1975 uses, in the waters of the basin over a 42-year period at the international boundary range from 350 mg/L to 1420 mg/L for the East Poplar River, from 530 mg/L to 770 mg/L for the

TABLE II-6

Comparison of Predicted TDS Values (42 years) with the Long-Term (10-year) and the Short-Term (3-consecutive months) Water Quality Objectives

| Scenarios | Violations[a] [b] Long-Term[c] 1000 mg/L | Violations Short-Term[d] 1500 mg/L |
|---|---|---|
| **East Poplar River at International Border** | | |
| Historical, 1975 uses only | 0 | 2 |
| One Power Plant, 1985 uses, apportionment | 8 | 2 |
| Two Power Plants, 1985 uses, apportionment | 19 | 9 |
| **East Poplar River Near Mouth** | | |
| Historical, 1975 uses only | 0 | 0 |
| One Power Plant, 1985 uses, apportionment | 7 | 0 |
| Two Power Plants, 1985 uses, apportionment | 18 | 5 |
| **Poplar River North of Indian Reservation** | | |
| Historical, 1975 uses only | 0 | 0 |
| One Power Plant, 1985 uses, apportionment | 0 | 0 |
| Two Power Plants, 1985 uses, apportionment | 0 | 0 |

(a) There were no violations at other sampling locations throughout the basin under the above scenarios.

(b) Degree of exceedence is not known.

(c) Maximum possible is 33.

(d) Maximum possible is 126.

Poplar River and from 420 mg/L to 750 mg/L for the West Poplar River. However, during the irrigation period (May 1 to September 30), the period of compliance with the TDS objectives, at no time during the 42 years of record was the long-term (10 year) objective of 1000 mg/L exceeded. The short-term (3-consecutive months) objective of 1500 mg/L was exceeded only twice during this period of record. (Table II-6).

The installation of a 600 megawatt power plant on the East Poplar River just north of the international border, as originally designed, is predicted to increase the monthly flow-weighted mean values of TDS in the waters of the East Poplar River crossing the international border over the irrigation period (May 1 to September 30) from 695 mg/L to 1060 mg/L. Extrapolating the 42-year water quality record and considering 1985 water uses, it is predicted that the long-term (10-year) objective will be violated 19 times and the short-term (3-consecutive months) objective 9 times (Table II-6). This effect will be experienced throughout the length of the East Poplar River (Table II-6). However, below its confluence with the Poplar River, at a location just north of the Fort Peck Indian Reservation, the predictions indicate no violations of either the long-term or short-term objective.

The effects of water quality apportionment on TDS concentrations in the waters of the Poplar and West Poplar Rivers at the international boundary are predicted to be minimal. For example, the monthly flow-weighted mean values over the irrigation period (May 1 to September 30) were increased for the Poplar River by 6 mg/L and for the West Poplar River by 76 mg/L.

The predictions indicate that by the time the waters of the Poplar River reach the Fort Peck Indian Reservation the TDS concentrations will not be in violation of the objectives.

Boron

The predicted historical mean monthly flow-weighted values for boron, based on 1975 uses, in the waters of the basin over a 42-year period at the international boundary range from 0.5 mg/L to 2.9 mg/L for the East Poplar River, from 0.7 mg/L to 1.1 mg/L for the Poplar River and from 0.7 mg/L to 1.0 mg/L for the West Poplar River. During the irrigation period (May 1 to September 30) these values were 1.0 mg/L to 1.4 mg/L, 0.8 mg/L to 1.0 mg/L, and 0.7 mg/L to 0.9 mg/L, respectively. The values are well below both the long term (5 mg/L) and the short term (8 mg/L) objectives (Table II-7).

The 600 megawatt power plant operation on the East Poplar River just north of the international border, as originally designed, is predicted to increase the monthly flow-weighted mean values of boron in the waters of the East Poplar River at the international

TABLE II-7

Comparison of Predicted Boron Values (42 years) with the Long-Term (10-year) and the Short-Term (3-consecutive months) Water Quality Objectives

| Scenarios | Violations (a) (b): Long-Term (c) 5 mg/L | Short-Term (d) 8 mg/L |
|---|---|---|
| **East Poplar River at International Border** | | |
| Historical, 1975 uses only | 0 | 0 |
| One Power Plant, 1985 uses, apportionment | 21 | 2 |
| Two Power Plants, 1985 uses, apportionment | 33 | 63 |
| **East Poplar River Near Mouth** | | |
| Historical, 1975 uses only | 0 | 0 |
| One Power Plant, 1985 uses, apportionment | 0 | 0 |
| Two Power Plants, 1985 uses, apportionment | 26 | 24 |
| **Poplar River North of Indian Reservation** | | |
| Historical, 1975 uses only | 0 | 0 |
| One Power Plant, 1985 uses, apportionment | 0 | 0 |
| Two Power Plants, 1985 uses, apportionment | 0 | 0 |

(a) There were no violations at other sampling locations throughout the basin under the above scenarios.

(b) Degree of exceedence unknown.

(c) Maximum possible is 33.

(d) Maximum possible is 126.

boundary over the irrigation period (May 1 to September 30) from 1.3 mg/L to 8.3 mg/L. Extrapolating the 42-year water quality record and considering 1985 uses, it is predicted that the long-term (10-year) objective will be violated 33 times and the short-term (3-consecutive months) objectives 63 times (Table II-7). This effect will be experienced throughout the length of the East Poplar River (Table II-7). However, on the Poplar River, at a location just north of the Fort Peck Indian Reservation, the predictions indicate no violations of either the long-term or short-term objectives (Table II-7).

The effects of water quality apportionment on boron concentrations in the waters of the Poplar and West Poplar Rivers are predicted to be insignificant.

The predictions indicate that by the time the waters of the Poplar River reach the Indian Reservation these monthly flow-weighted mean boron concentration over the irrigation period (May 1 to September 30) will be reduced to 2.9 mg/L, well below the objectives.

Sulphates

The predicted historical mean monthly flow-weighted values for sulfate, based on 1975 uses, in the waters of the basin over a 42-year period at the international boundary range from 7.0 mg/L to 370 mg/L for the East Poplar River, from 110 mg/L to 190 mg/L for the Poplar River and from 110 mg/L to 160 mg/L for the West Poplar River. During the irrigation period, these values were 130 mg/L to 200 mg/L, 130 mg/L to 170 mg/L and 130 mg/L to 140 mg/L, respectively. During this period, also, 90 percent of the sulfate values for the East Poplar River were less than 470 mg/L, for the Poplar River less than 200 mg/L and for the West Poplar River less than 490 mg/L. All of these values are well below the 800 mg/L objective limit for sulfate.

The 600 megawatt power plant operation on the East Poplar River just north of the international boundary, as originally designed, is predicted to increase the monthly flow-weighted mean values of sulfate in the waters of the East Poplar River at the international boundary from 197 mg/L to 390 mg/L. This higher value for sulfate is well below the 800 mg/L objective limit for sulfate.

The effects of the water quantity apportionment on sulfate concentration in the waters of the Poplar and West Poplar Rivers are predicted to be minimal.

The predicted effect of the power plant on the monthly flow-weighted mean sulfate concentrations in the waters of the Poplar River as they enter the Fort Peck Indian Reservation is to increase the values from 240 mg/L to 290 mg/L.

## Sodium Adsorption Ratio (SAR)

The historically predicted monthly flow-weighted mean values for SAR in the waters of the basin over the irrigation period (May 1 to September 30) for a 42-year period of record at the international boundary ranged from 3 to 4 for the East Poplar River, from 4 to 5 for the Poplar River and from 5 to 6 for the West Poplar River. These ratios are well below the objective limit of 10.

The 600 megawatt power plant operation on the East Poplar River just north of the international boundary, as originally designed, is predicted to increase the SAR in the waters of the East Poplar River at the international boundary during the irrigation period (May 1 to September 30) from 3 to 5. This increase is below the objective limit.

The effects of water quality apportionment on the SAR values in the waters of the Poplar and West Poplar Rivers are predicted to be insignificant.

The predicted effects of the power plant on the SAR values in the waters of the Poplar River as they enter the Fort-Peck Indian Reservation is to increase the mean ratios for the irrigation period (May 1 to September 30) from 5.0 to 5.5. However, as pointed out in the Surface Water Quality Committees' report these predictions are probably too low.

## Mitigation Requirements

The comparison of the selected predicted water quality parameters with the water quality objectives showed that the power plant operation would increase the concentrations of boron and total dissolved solids in the waters of the East Poplar River to levels that exceeded the objectives for these constituents for a major part of the irrigation period and, therefore, required mitigative measures.

This information was passed to the Plant Mine and Reservoir Operations Committee for action. The mitigative measures proposed and the results determined by that Committee follow:

Boron: the mitigation proposed consists of a combination ash recirculating lagoon system with a) no blowdown or b) a limited blowdown treated to a reservoir water quality level or better. The suggested rates of seepage for the mitigative option are:

a) 1.5 litres per second to the East Poplar River below Morrison Dam, and

b) 5 litres per second to Cookson Reservoir

The seepage flow was assigned the following concentrations: calcium 600 mg/L, magnesium 500 mg/L, sodium plus potassium 700 mg/L, chloride 70 mg/L, sulfate 1500 mg/L, total alkalinity 800 mg/L, and boron 50 mg/L.

The seepage control options and influencing factors that could be used to achieve the above noted seepage rates are:

a) a system of exterior drains and pumpwells with pump back to the lagoons,

b) lining the lagoons,

c) remove the lagoons to an area which will ensure their southernmost boundary remains well north of Morrison Dam and adequately separated from the high groundwater gradient area below Morrison Dam,

d) raising the water level in the recirculating lagoon as the ash surface raises, thereby ensuring a significant ash layer in the lagoon before there is the need to operate under maximum hydraulic head, and

e) operating only one lagoon at a time, thereby decreasing the area contributing to both seepage loses and to evaporation.

The predicted results of the combination ash recirculating lagoon system mitigation are shown in Table II-8.

The predicted results of the proposed mitigation show that the boron concentrations in the East Poplar River will be reduced to levels in complete compliance with the objectives.

The flow-weighted mean value for boron during the irrigation period (May 1 to September 30) was reduced from 8.3 mg/L to 3.2 mg/L as a result of the proposed mitigation.

The combination ash recirculating lagoon system mitigation measure plus reservoir water lime softening are predicted to produce a water with a maximum 10-year mean of 3.8 mg/L boron, a maximum May to September mean of 5.4 mg/L boron and a May to September mean boron level of 2.9 mg/L at the international boundary.

The combination ash recirculating lagoon system mitigation measure plus the diversion of water from the Poplar River or from the East Poplar River upstream of Cookson Reservoir are predicted to produce a water with a maximum 10-year mean of 2.6 mg/L boron, a maximum May to September mean of 3.1 mg/L boron and a May to September mean boron level of 2.1 mg/L at the international boundary.

TABLE II-8

Comparison of Predicted Boron Concentrations in the East Poplar River with the Long-Term and Short-Term Water Quality Objectives after Proposed Mitigation (Two Power Plants, 1985 uses, apportionment)

| Locations | Violations[a] | | | |
|---|---|---|---|---|
| | Long-Term (5 mg/L)[b] | | Short-Term (8 mg/L)[c] | |
| | Before Mitigation | After Mitigation | Before Mitigation | After Mitigation |
| East Poplar River at International Border | 33 | 0 | 63 | 0 |
| Poplar River North of Fort Peck Indian Reservation | 0 | 0 | 0 | 0 |

(a) Degree of exceedence unknown

(b) Maximum possible is 33

(c) Maximum possible is 126.

Total Dissolved Solids

The mitigation proposed is that one of two measures be put into effect within one month upon the first excess of a 1000 mg/L TDS concentration in Cookson Reservoir after the spring peak flow. These measures are:

1) Install and operate a reservoir water softening facility to maintain TDS levels crossing the international border within the objective limits. This to be accomplished by treating cooling water, mine dewatering discharge or both. The facility is to be constructed and operational within one year of the first measured post-spring freshet TDS greater than 1000 mg/L.

2) Construct a storage and diversion facility on the Poplar River or on the East Poplar River upstream of Cookson Reservoir capable of containing and conveying sufficient spring runoff water to maintain TDS levels within the objective limits. This is to be accomplished by supplying or diluting either or both of the release-on-demand or low-flow discharges from Cookson Reservoir. Such facilities could be operational within two years of the first measured post-spring freshet TDS greater than 1000 mg/L.

   The predicted results of the lime softening mitigation are shown in Table II-9

The proposed mitigation of demand releases from either the Poplar River or from storage above Cookson Reservoir is predicted to result in no violations of the long-term (1000 mg/L) or the short-term (1500 mg/L) TDS water quality objectives during the irrigation period (May 1 to September 30).

The reservoir water lime softening measure is predicted to produce a water with a maximum 10-year mean of 1054 mg/L of TDS, a maximum May to September mean of 1375 mg/L TDS and a May to September TDS mean level of 853 mg/L.

The storage and diversion of water from the Poplar River or from the East Poplar River upstream of Cookson Reservoir is predicted to produce a water with a maximum 10-year mean of 958 mg/L TDS, a maximum May to September mean of 1218 mg/L TDS and a May to September TDS mean level of 825 mg/L.

TABLE II-9

Comparison of Predicted TDS Concentrations in the East Poplar River with the Long-Term and Short-Term Water Quality Objectives after Proposed Lime Softening Mitigation (Two Power Plants, 1985 uses, apportionment)

| Locations | Violations (a) | | | |
|---|---|---|---|---|
| | Long-Term Before Mitigation | (1000 mg/L)[b] After Mitigation | Short-Term Before Mitigation | (1500 mg/L)[c] After Mitigation |
| East Poplar River at International Boundary | 19 | 7 | 9 | 2 |
| Poplar River North of Fort Peck Indian Reservation | 0 | 0 | 0 | 0 |

(a) Degree of exceedance unknown

(b) Maximum possible is 33

(c) Maximum possible is 126

Mitigation Measures Effects on Water Uses in the East Poplar and Poplar Subbasins

At its February meeting in Denver, Colorado, the International Poplar River Water Quality Board directed this committee to research and to provide information on the value effects relating to downstream uses at 3.0, 4.0, 5.0 and 8.0 mg/L boron and at 1000 and 1500 mg/L TDS in the waters of the East Poplar River at the international boundary.

The only value effects directly related to these substances in waters on water uses that the Committee could get hard data on was their effects on the yields of barley and alfalfa grown under irrigation, the major crops grown under irrigation in the basin.

The committee's research revealed that:

1) the long-term (10-year) monthly flow-weighted mean natural values for boron and TDS in East Poplar River waters at the international boundary were approximately 2.0 and 670 mg/L respectively.

2) (a) no detrimental effect on alfalfa yields up to 15 mg/L boron

(b) the average barley yields in bushels per acre by subbasins were calculated as:

| Subbasin | Boron Concentrations (mg/L) 2.0 | 3.0 | 4.0 | 5.0 | 8.0 |
|---|---|---|---|---|---|
| East Poplar River | 74* | 69 | 66 | 63 | 52 |
| Poplar River to Indian Reservation | 75 | 73 | 71 | 70 | 66 |
| Poplar River Indian Reservation | 76 | 74 | 72 | 72 | 69 |

* bushels per acre. Based on 80 bu/ac yield at trace concentrations of boron.

3) the average alfalfa yeilds throughout the East Poplar and Poplar subbasins were determined as 5 tons per acre.

4) the 1975 crop acreages for the subbasins that will be affected by the power plant operation were as follows:

| Subbasin | Barley | Alfalfa | Totals |
|---|---|---|---|
| East Poplar River | 0 | 65 | 65 |
| Poplar River | 45 | 1324 | 1369 |

5) the 1978 price of malt barley was $2.25 per bushel and of alfalfa $50.00 per ton.

Boron: from the information presented in Annex C, on barley yields loss due to increasing boron concentrations in irrigation waters and utilizing the above information, barley crop loss in U.S. dollars per acre year were calculated for long-term average boron concentrations of 2.0, 3.0, 4.0, 5.0 and 8.0 mg/L, during the irrigation season, at the international border for the East Poplar River and Poplar River subbasins (Figure 2).

The results of these calculations are given in Figure 3 for the East Poplar subbasin, Figure 4 for the Poplar subbasin from the mouth of the East Poplar River to the north boundary of the Fort Peck Indian Reservation and Figure 5 for the Fort Peck Indian Reservation.

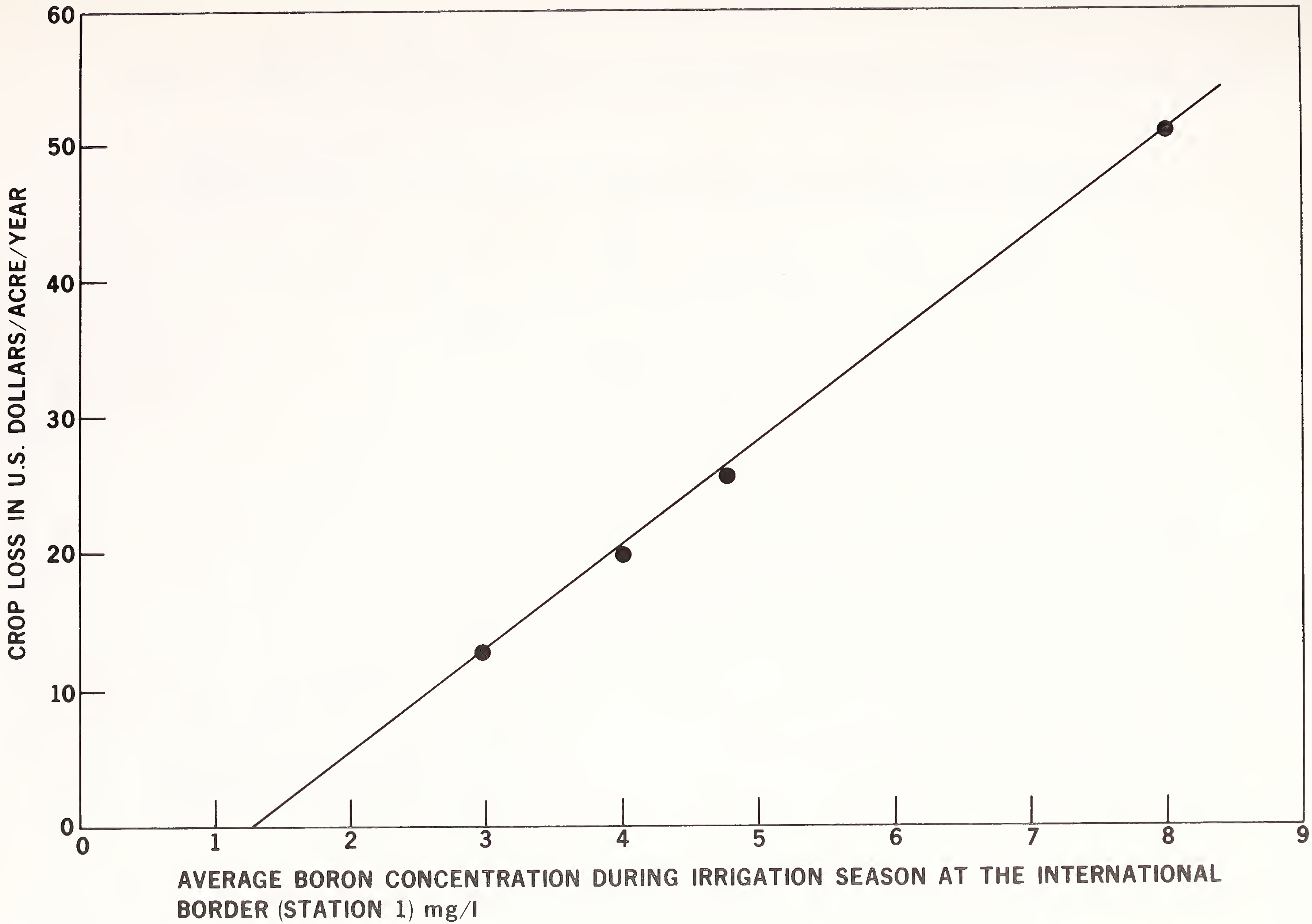


Figure 3 Barley crop loss vs Boron concentration, East Fork-Poplar River.

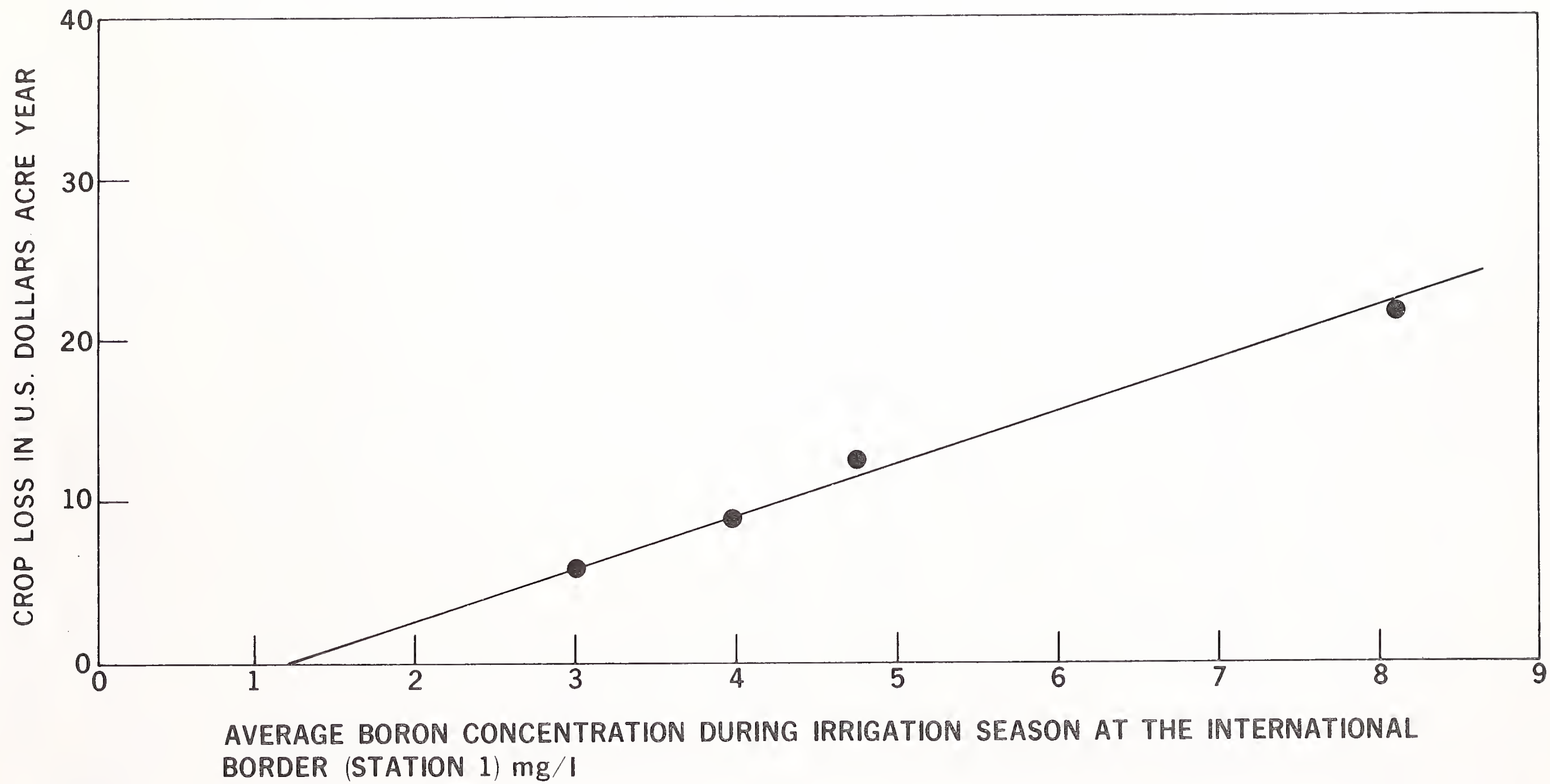


Figure 4 Barley crop loss vs Boron concentration, mouth of East Fork to Reservation Boundary-Poplar River.

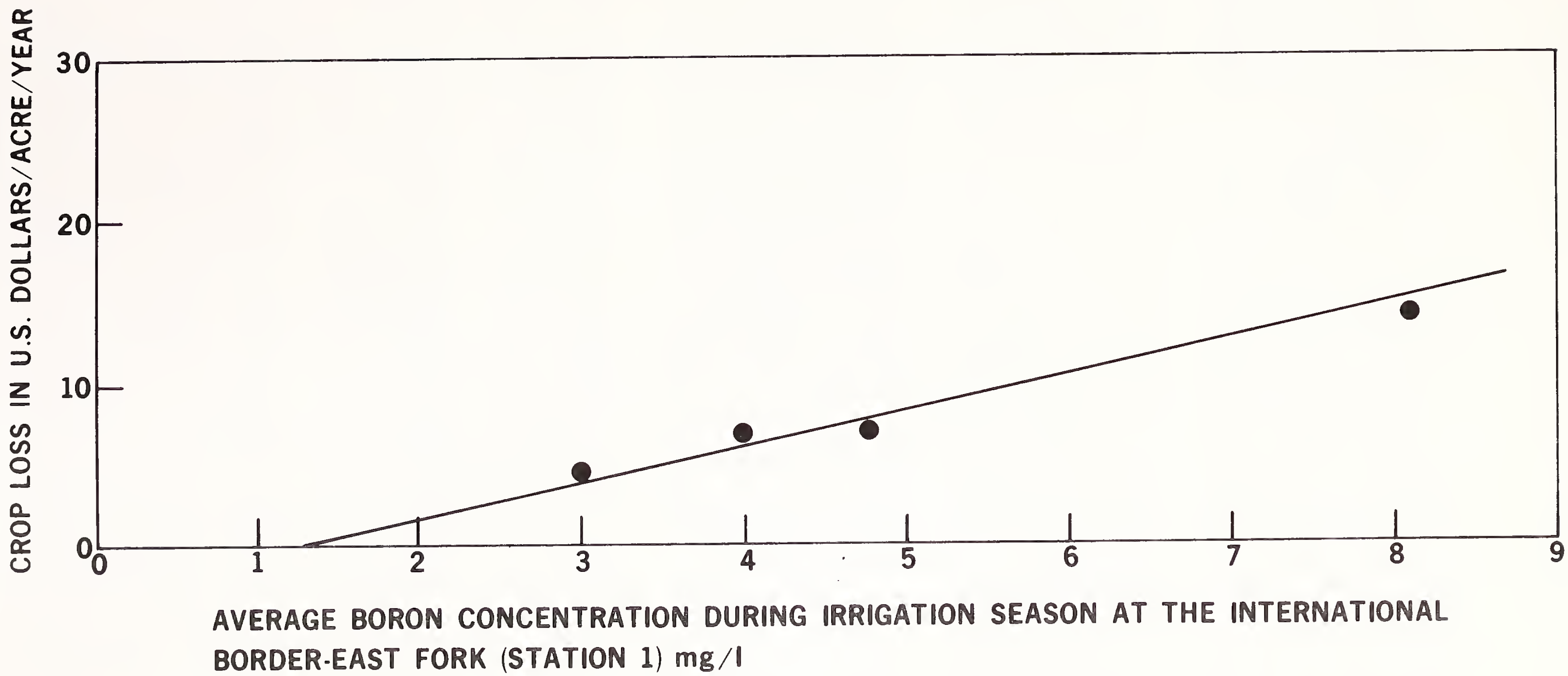


Figure 5 Barley crop loss vs Boron concentration, Reservation Boundary-Poplar River (Station 8).

Total Dissolved Solids: At the present time, there may be sufficient water available (and perhaps used) to maintain acceptable salt concentrations in most of the soils which are irrigated. However, judging from the appearance of some of the irrigated fields present in the basin, the necessary leaching is not being achieved in all cases. This lack of successful leaching may result from soil characteristics. That is, these soils may not be porous enough to allow the necessary water to pass through. It may also be due to improper application of water.

At predicted future development levels (1985 or 2000) surplus water will not generally be available. When this occurs, TDS concentration increases will generally cause a loss. These losses can be estimated either by assuming less land will be irrigated with slightly more water or by assuming projected irrigation development levels are reached but with a slight yield reduction. Because there are fewer uncertainties in assuming yield reductions, this approach is used.

From the information presented in Annex C, the above information and using flows and TDS values from projected historical water quality and from the predicted water quality resulting from the operation of two power units plus full development in Canada, Figures 6, 7, and 8 were developed. For figures 6 and 7, the mean of the median values for the irrigation season were used and converted to the expected TDS in the middle of the reach for the two upper reaches. For the lower reach, Figure 8, it was assumed that the water would be used near the reservation boundary and the expected TDS at that point was used.

Figure 9 was developed to show the potential losses when storage was developed near the reservation boundary. This figure uses the yield and costs figures given above but used the yearly flow-weighted TDS concentration increases resulting from Canadian development.

It is emphasized that these loss figures are only rough estimates. There may be considerable error due to soil characteristics of the land to be developed, management techniques used, yields and value of alfalfa, and the applicability of the yield reduction versus TDS concentration relationships assumed from annex C.

The committee's research also revealed that the Cookson Reservoir on the East Poplar River could have beneficial, as well as detrimental effects on water uses in the East Poplar and Poplar subbasin. It will reduce the threat of spring flooding and under the terms of the Apportionment Agreement's water release on demand provision, will supply water when needed to satisfy special needs downstream. Should this demand release water be called for during late July or August and used for irrigation it could increase crop yields by a realistic estimate of 10 percent or more. In addition, this water could be of a better quality than the typical low flow water during July and August.

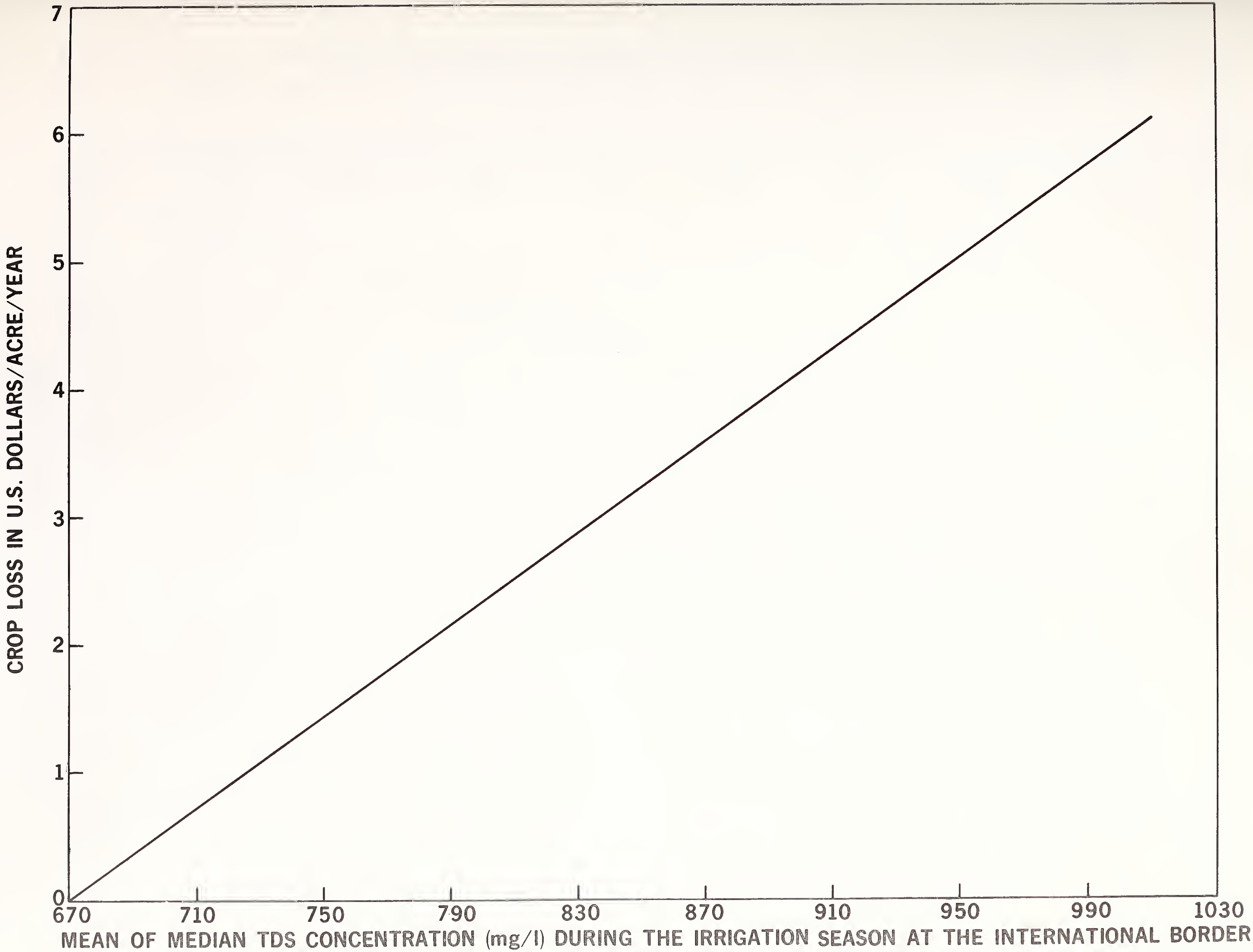


Figure 6 Potential crop loss in the East Poplar sub-basin vs TDS concentration at the International Border

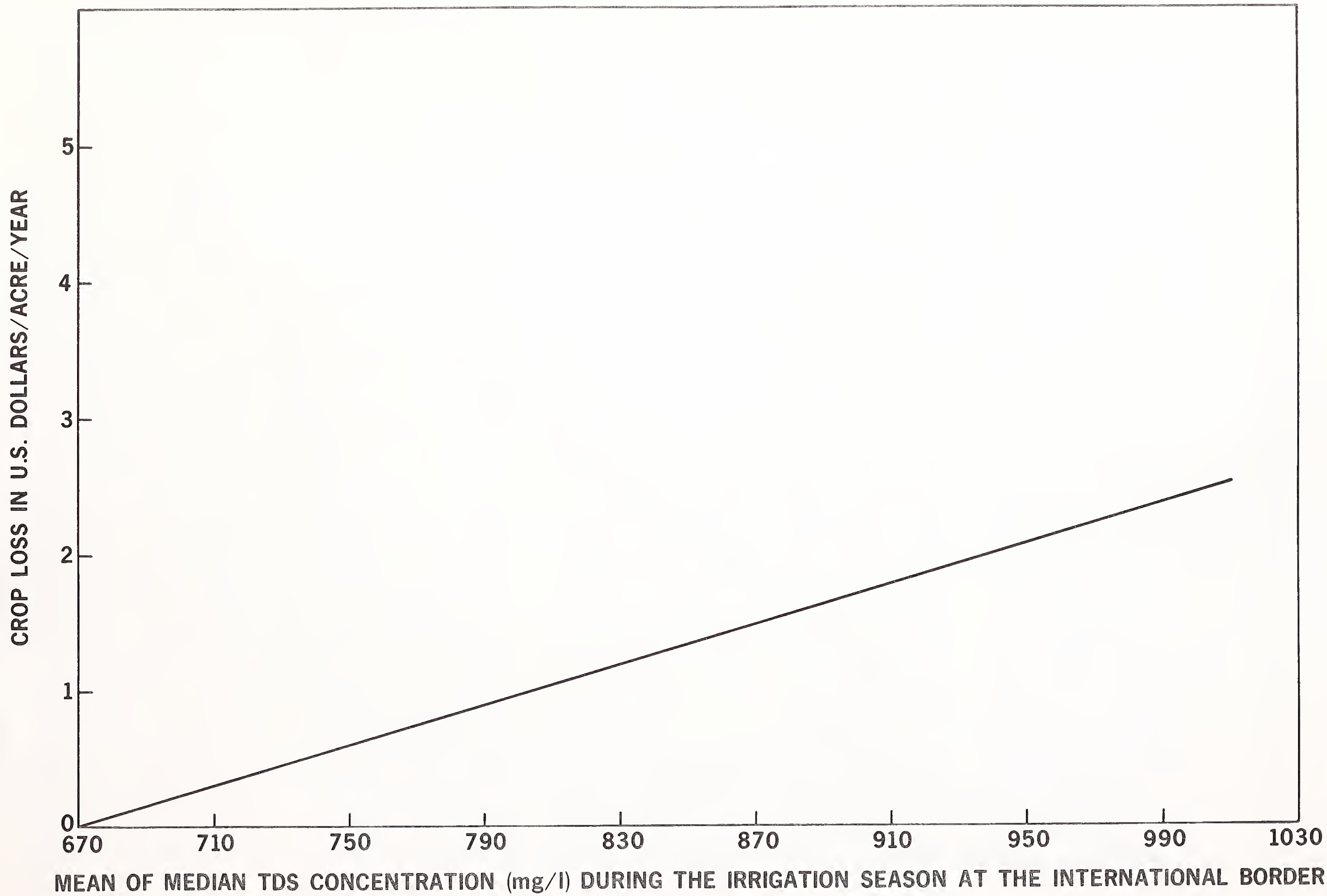


Figure 7 Potential crop loss in the Poplar River basin (between the middle Fork and the Reservation) vs TDS concentration at the International Border

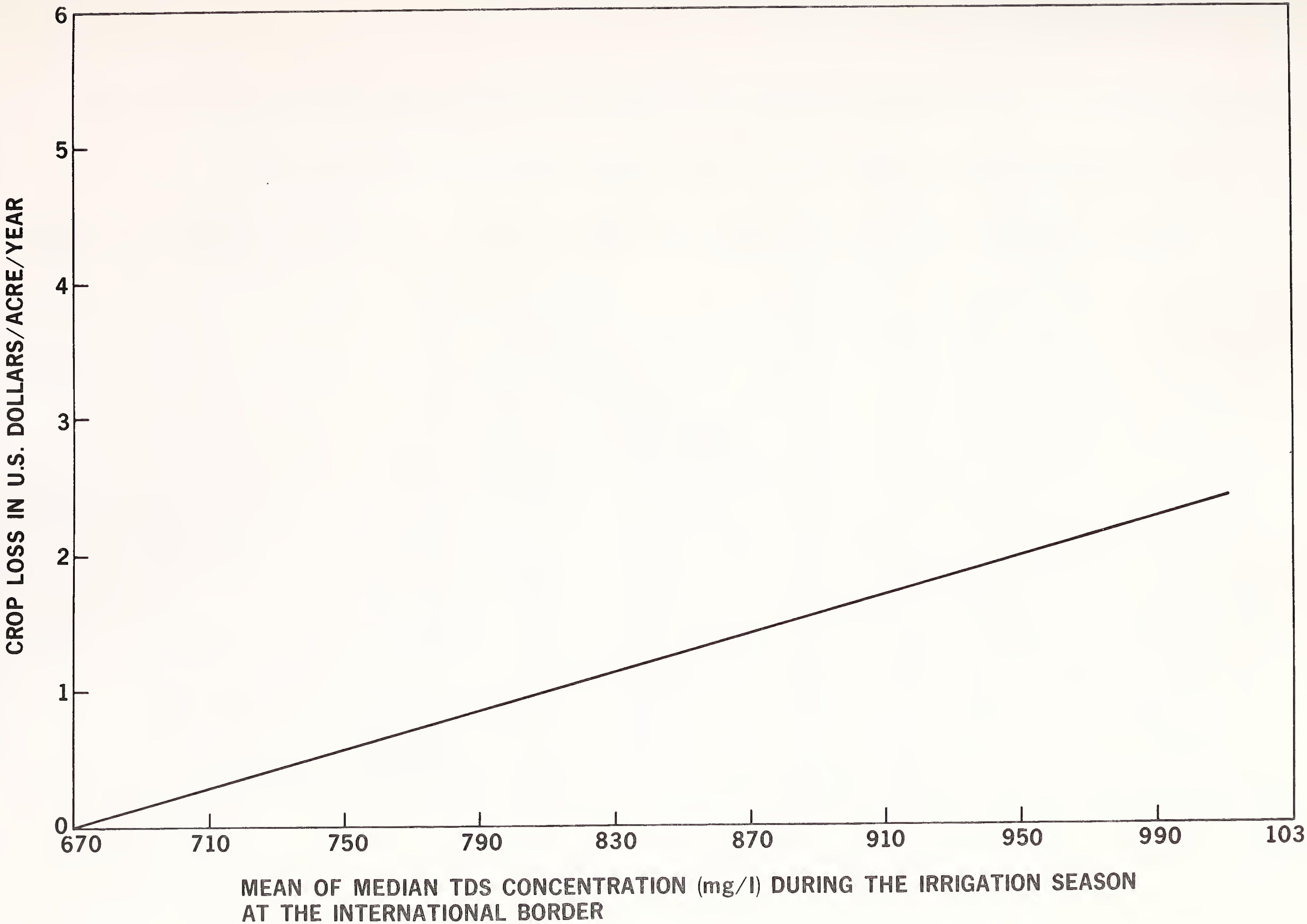


Figure 8 Potential crop loss on the Reservation vs TDS concentration at the International Border

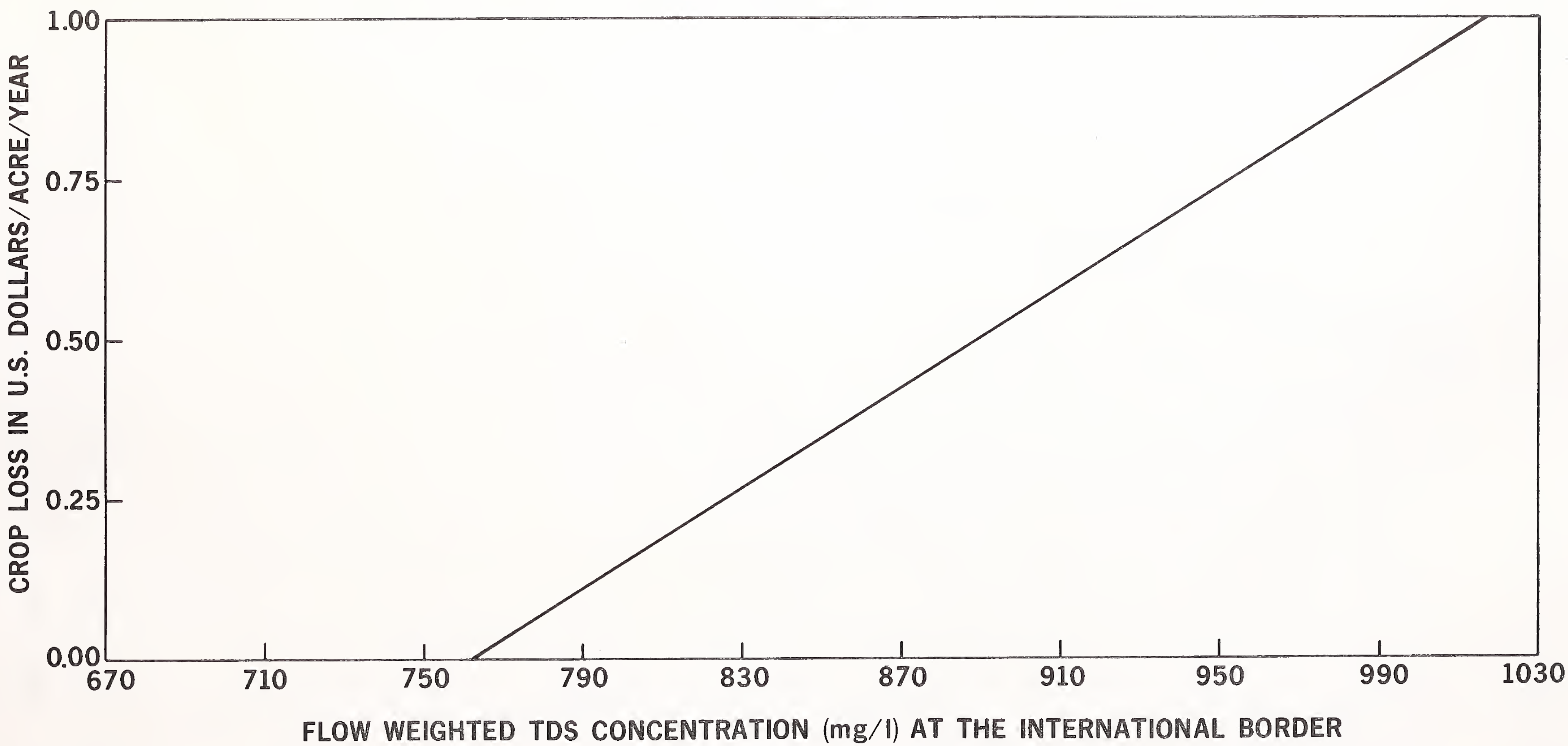


Figure 9 Potential crop loss on the Reservation vs TDS concentration at the International Border

The committee could not reach agreement on how this information should be used to determine the value effects of the plant operation on downstream water use for irrigation purposes. Therefore, two alternative interpretations of these value effects are presented for the Board's consideration and use as they deem advisable.

Alternative 1 - Interpretation of Value Effects

Demand release water used exclusively or partially for irrigation purposes violates the intent of the water release on demand provision of the Apportionment Agreement and thus, should be considered as a benefit to farmers growing crops under irrigation.

The crop value loss material presented above is acceptable only if crop value gains are also taken into account in determining the overall value effects of the Cookson Reservoir on downstream irrigation water use.

Utilizing the presented crop value loss and gain material, the information presented in Table II-10 was calculated. An example of the calculations follows:

Assumptions:
1. Water containing 5.0 mg/L Boron and 1000 mg/L TDS.
2. All demand release water used for late irrigation.
3. 10% of crop increase in yield.

Crop Value Losses

From figures 4, 6 and 7, barley crop value loss is \$12.00 per acre per year and alfalfa crop value losses are \$5.75 and \$2.50 per acre per year.

| | | | |
|---|---|---|---|
| Barley loss | = 45 ac./yr | X \$12.00 | = \$ 540.00 |
| Alfalfa losses | = 65 ac./yr | X \$ 5.75 | = \$ 374.00 |
| | =1324 ac./yr | X \$ 2.50 | = \$3310.00 |
| | | Total | = \$4224.00 |

Crop Value Gains

1. Annual crop value with no late irrigation

| | | | |
|---|---|---|---|
| Barley | - 45 ac/yr. X 63 bu/ac | X \$ 2.25/bu | = \$ 6 379 |
| Alfalfa | - (65 ac/yr. X 5 tons/ac | X \$50.00/ton) - \$374.00 loss | = \$ 15 876 |
| | - (1324 ac/yr X 5 tons/ac | X \$50.00/ton - \$3310.00 loss | = \$327 690 |
| | | | = \$349 945 |

2. Annual crop value gain with late irrigation
   - 10% crop yield increase

| | | | | | |
|---|---|---|---|---|---|
| Barley | - 45 ac/yr X 69.3 bu/ac | X $ 2.25/bu | | = | $ 7 017 |
| Alfalfa | - (65 ac/yr X 5.5 tons/ac | X $50.00/ton | - $374.00 loss | = | $ 17 501 |
| | - (1324 ac/yr X 5.5 tons/ac | X $50.00/ton | - $3310.00 loss | = | $360 790 |
| | | | Total | = | $385 308 |

3. Net crop gain over loss = $385 308 - $349 945 = $35 363

Table II-10 presents a range of estimated annual crop value losses and gains at three levels of concentrations of boron and TDS in the waters of the East Poplar River at the international boundary under three assumed conditions of demand water releases on irrigation water use. Annual percentage losses and gains are also given.

Alternative 2 - Interpretation of Value Effects

The members of the United States section of the Uses and Water Quality Objectives Committee recognize that Cookson Reservoir, coupled with the apportionment schedule as recommended by the International Joint Commission, may prove to be beneficial to irrigated crop production along the East Poplar River and the Poplar River from Scobey to Poplar. However, we strongly oppose the view that such a benefit should be quantified and compared with the crop losses predicted to result from changes in water quality. The reasoning behind our opposition to this concept is based upon the following assertion.

The benefits and disbenefits of the recommended apportionment agreement are balanced. Since the Poplar River apportionment proceedings were initiated largely by a proposal to construct a power plant and dam on the East Poplar River in Saskatchewan, it is reasonable to assume that in the process of negotiating an equitable apportionment, the Task Force first recognized Canada's eventual requirement of more than one half of the average annual flow of the East Poplar River, as measured at the international boundary. Although it is not practical to determine the precise order in which the benefits and disbenefits were traded off, it is likely that in response to the initial benefit granted Canada, an offsetting benefit to the United States might well have been the concept of releases on demand. Other benefits and disbenefits to both countries are evident in the recommended schedule; however, the principal objective of the negotiation process was obviously that of balancing benefits. We believe that such a balance exists.

TABLE II-10

Estimated Annual Crop Value Losses and Gains Under Assumed Conditions Based on 1975 Crop Yields and Acreages and 1978 Crop Values with a 600 Megawatt Power Plant in Operation

| Crop value losses and gains / Assumptions | 1. All demand release water used for late irrigation<br>2. 10% crop increase | | | 1. 50% demand release water used for late irrigation<br>2. 5% crop increase | | | 1. No demand release water used for late irrigation<br>2. 0% crop increase | | |
|---|---|---|---|---|---|---|---|---|---|
| Water Quality Conditions[a] | 3.0 mg/L B<br>900 mg/L TDS | 5.0 mg/L B<br>1000 mg/L TDS | 8.0 mg/L B<br>1500 mg/L TDS | 3.0 mg/L B<br>900 mg/L TDS | 5.0 mg/L B<br>1000 mg/L TDS | 8.0 mg/L B<br>1500 mg/L TDS | 3.0 mg/L B<br>900 mg/L TDS | 5.0 mg/L B<br>1000 mg/L TDS | 8.0 mg/L B<br>1500 mg/L TDS |
| Crop Value Loss in Dollars | 2 735 | 4 225 | 10 163 | 2 735 | 4 225 | 10 163 | 2 735<br>(0.9%) | 4 225<br>(1.4%) | 10 163<br>(3.2%) |
| Crop Value Gain in Dollars | 35 435<br>(9.0%) | 35 365<br>(8.5%) | 35 190<br>(7.0%) | 17 720<br>(4.0%) | 17 690<br>(3.5%) | 17 625<br>(2.0%) | 0 | 0 | 0 |

(a) Levels used from the Plant, Mine and Reservoir Committee

The proposal by the Canada section of this committee to resurrect just one of those benefits and attach a value to it, apart from the offsetting benefits of the entire apportionment package, fails to recognize the equitable nature of the recommended apportionment schedule. Their proposal falsely demonstrates a net benefit to the United States.

We believe that the assigning of values to any one of the benefits necessitates the same for all benefits. Surely, the Canadian section does not wish to completely reevaluate the benefits and costs to each country and to the Saskatchewan Power Corporation.

Assuming the recommended apportionment schedule will be adopted by the governments concerned, and depending upon the amount of runoff each spring, the United States will be entitled to reservoir releases of 370, 620, and 1230 $dm^3$ (300, 500 and 1000 ac-ft, respectively) on demand. Had the recommended apportionment schedule been in effect over the forty five years of hydrologic record in the basin, 370 $dm^3$ (300 ac-ft) would have been available to the United States on the average of two years out of ten, 620 $dm^3$ (500 ac-ft) would have been available five years out of ten, and 1230 $dm^3$ ( 1000 ac-ft) would have been available three years out of ten.

While it is reasonable to assume that a portion of these annual demand releases would be used to apply additional water to existing irrigated acreage or to permit an increase in the acreage irrigated, it is equally reasonable to assume that some portion would be used to protect instream flow values as well. Nevertheless, if the major portion of the demand releases is given to irrigation, the application of two to three inches of water per acre during the late irrigation season, where there has commonly been a shortage of water in this basin, could increase crop yields 10 percent or more. Albeit, such an increase in yield could occur only if the levels of certain chemicals in the demand release water, particularly boron or TDS, are not substantially increased over natural levels. Any measurable increase in the concentration of boron or TDS would require that some of the demand release water be used for leaching, but a substantial increase might require that all of it be used for leaching.

In light of the apprehension expressed by Montanans living in the Poplar River Basin over the presence of the power plant and its operation, we would emphasize to them that the reservoir may produce benefits to both irrigated crops and desirable aquatic organisms. However, we would also caution everyone concerned, particularly the Board and the Commission, against masking predicted water quality losses with a benefit that should not be considered out of context.

## Conclusions

The mitigation measures proposed will meet, with minor exceptions, the water quality objectives. The measures proposed, however, are predicted as having varying degrees of effect in reducing boron and TDS concentrations in the waters of the East Poplar River at the international border. The proposed measure of the combined ash recirculating lagoon system with seepage of 1.5 L/s to the East Poplar River at 5.0 L/s to the reservoir plus demand water releases to come from the Poplar River or from storage above Cookson Reservoir are predicted to give the lower boron and TDS concentrations of the recommended mitigation measures as shown below.

Either of these recommended measures will provide a water quality in the East Poplar River at the international boundary within one standard deviation of the actual measured boron and TDS concentrations between the years of 1973 to 1977.

Predicted Water Quality Concentrations in the Waters of the East Poplar River at the International Border with Mitigation

| Mitigation Measure | Parameters | | Time Frame Means |
|---|---|---|---|
| | Boron (mg/L) | TDS (mg/L) | |
| 2 units; combined ash recirc. lagoon; seepage of 1.5 L/s to river, 5.0 L/s to reservoir; reservoir water lime softened | 5.4<br>2.9<br>3.8<br>2.9 | 1375<br>853<br>1054<br>828 | Max. May to Sept. Mean<br>Mean May to Sept.<br>Max. 10-year Mean<br>Mean Annual |
| 2 units, combined ash recirc. lagoon; seepage of 1.5 L/s to river, 5.0 L/s to reservoir; demand release from Poplar River or storage above Cookson Reservoir | 4.1<br>2.2<br>2.8<br>2.7 | 1300<br>733<br>904<br>857 | Max. May to Sept. Mean<br>Mean May to Sept.<br>Max. 10-year Mean<br>Mean Annual |

## Locations of Non-Compliance with Water Quality Objectives Where Remedial Measures are not Practicable

An analysis of the predicted water quality results, including 1985 uses and full apportionment, revealed that at no time were the water quality objectives, for all parameters, violated by causes other than by man's activities in this basin.

The predicted predevelopment water quality results, however, revealed that the total dissolved solids were naturally in excess of 1000 mg/L during the months of December through February in the waters of the East Poplar and Poplar Rivers. The average flow-weighted mean value for TDS during this period was 1270 mg/L with 10 percent of the value exceeding an average of 1500 mg/L. Since these values occur during the non-irrigation period and since the volumes of the flow during this period are less than one cubic hectometre per month, it is predicted that TDS values of this magnitude will have little effect on the quality of water of any impoundment that may be caused to occur at any downstream location for irrigation purposes.

The predictions for boron and sulfates revealed that these parameters do not violate the objectives even during the winter period.

## Methodologies for Compliance Monitoring of Water Quality Objectives

In the application of water quality objectives for the Poplar River Basin and the water quality limits required at international boundary crossings of the Poplar River System to ensure compliance with objectives throughout the basin, it is extremely important that the results of any physical, chemical or biological investigation of water are reliable and comparable within this water system.

These provisions can be met for this waterway by closely following the recommendations set out in Annex E for sampling, preserving and handling water samples and the analyses of water samples.

It cannot be stressed too strongly that the results of any physical, chemical or biological investigation are only as good as the water samples received for analysis and the products of the analysis are useful only if they are comparable and reliable.

# CONCLUSIONS

The following conclusions are based on the predicted water quality results of a computer model developed by the Surface Water Quality Committee.

1) The water quality objectives as developed for the waters of this basin should provide an adequate degree of protection for the defined water uses, if used conservatively and coupled with a well designed monitoring program.

2) The water quality objectives developed for the waters of this basin were based on "best available scientific information", therefore, they are not, nor can they be expected to be the last word on the quality of the water needed to ensure the protection of the multipurpose use of the waters of this basin. New scientific information is constantly being developed. Social and economic trends are in continuous flux. Thus, it must be expected that these objectives will require revision at least once every five years.

3) The apportioning of water quality in accordance with the recommended Apportionment Agreement should have little effect on downstream water quality.

4) The 600 megawatt power plant development on the Canadian portion of the East Poplar River should have little effect on downstream water quality when operated in accordance with the measures defined as a result of required mitigation.

## Recommendations

The Committee recommends that:

1) The water quality objectives set out in this report be accepted for use in the Poplar River basin and that they be required to be reviewed at least every five years.

2) Water quality monitoring be initiated throughout the basin and especially at the international border to ensure that the water quality objectives are not violated. The monitoring programs to be conducted in accordance with the methodologies described in Annex E.

# PART III

# ANNEXES

ANNEX A

WATER QUALITY OBJECTIVES

FOR

MUNICIPAL AND DOMESTIC POTABLE WATER SUPPLY

## ANNEX A - WATER QUALITY OBJECTIVES

## FOR

## MUNICIPAL AND DOMESTIC POTABLE WATER SUPPLY

### Introduction

The objectives recommended to protect municipal and domestic water supplies are summarized in the initial table. These objectives are based on a review of the references listed and our professional judgement.

Municipal and domestic water uses include water needed for human consumption, household use, dairy production, livestock and garden irrigation. We have assumed:

-that the water for domestic use would be disinfected by chlorination or other suitable means, prior to consumption.

-that the proposed objectives listed were for the total constituent.

PROPOSED WATER QUALITY OBJECTIVES

FOR

MUNICIPAL AND DOMESTIC POTABLE SUPPLY

| Parameter | Level (mg/L unless noted) |
|---|---|
| Total Coliforms | Geometric mean less than 5 000 organisms per 100 mls<br>Maximum less than 20 000 organisms per 100 mls |
| Fecal Coliforms | Geometric mean less than 1 000 organisms per 100 mls<br>Maximum less than 2 000 organisms per 100 mls |
| Arsenic | 0.05 |
| Cadmium | 0.01 |
| Chromium | 0.05 |
| Copper | 1.0 (not a health hazard) |
| Fluoride | 1.5 |
| Iron | 0.3 (not a health hazard) |
| Lead | 0.05 |
| Manganese | 0.05 (not a health hazard) |
| Mercury | 0.002 |
| Nitrate | 10 (as nitrogen) |
| Sulphate | 800 (not a health hazard) |

## ARSENIC (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 0.05 | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.10 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.05 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 0.01 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.01 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 | 7. Water Quality Standard - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Reports maximum standards of 0.05 and 0.2 | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

CADMIUM (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 0.01 | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.01 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.01 | 3. Quality Criteria for Water. U.S. Environmental Protection Agency (July 1976). |
| 0.01 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.01 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.01 | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Reports limits of 0.1, 0.01, and 0.05. | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

CHROMIUM (mg/L)

| Recommended Objectives | | REFERENCES |
|---|---|---|
| 0.05 | 1. | A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.05 | 2. | "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.05 | 3. | Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 0.05 | 4. | "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 | 5. | "Table 1: Surface Water Quality Objectives", Water Quality Objectives. Saskatchewan Environment. |
| | 6. | "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 as $Cr^{+6}$ | 7. | Water Quality Standards - $B\text{-}D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| On basis animal experiments states man should tolerate 5.0 $Cr^{+6}$ | 8. | McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. | 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## COPPER (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 1.0 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 1.0 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 1.0 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.02 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 1.0 maximum where other supplies are/ or can be made available | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Threshold taste concentration ranges from 1.0 to 2.0 | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Review", unpublished to date. |

## FECAL COLIFORMS

| Recommended Objectives | REFERENCES |
|---|---|
| For drinking water only, not applicable to water source. | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| Geometric mean not to exceed 2 000 organisms/100 mls. | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 9 out of 10 samples should have less than 1 000 organisms/100 mls. | 4. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 5. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)". Water Quality Objectives, Saskatchewan Environment. |
| | 6. Water Quality Standards - $B\text{-}D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to:<br><br>Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| | 7. McKee and Wolf: "Potential Pollutants". Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 8. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

FLUORIDE (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 2.0 - 2.2 | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| Depends on air temperature | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 1.5 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 1.5 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| Depends on air temperature | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| 1.0 more beneficial than detrimental | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## IRON (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.3 soluble | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.3 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 0.3 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.3 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| up to 1.0 | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.3 maximum where other supplies are/or can be made available. | 7. Water Quality Standards - $B\text{-}D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Taste threshold varies with individuals. | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

LEAD (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 0.05 | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.05 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.05 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 0.05 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 | 7. Water Quality Standard - $B-D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Reports standards of 0.05 | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## MANGANESE (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.05 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.05 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 0.05 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| up to 0.5 | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 0.05 maximum where other supplies are/ or can be made available | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Limiting concerns of 0.02 - 0.5 reported | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## MERCURY (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 0.002 | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 0.002 | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 0.002 | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Reports that adults can drink 4 to 12 mg/day | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## NITRATE (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| 10 as N | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 10 as N | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| 10 as N | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 40 as $NO_3$ | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| Values in excess of 40 as $NO_3$ are considered unsafe for infants up to 6 months | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 45 as $NO_3$ maximum where other supplies are/or can be made available | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| Water with more than 10 as N should not be used for infants | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## SULPHATE (mg/L)

| Recommended Objectives | REFERENCES |
|---|---|
| | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| 250 where sources with lower concentrations are available | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973) |
| 250 to protect transients to the area | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| 500 | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| up to 800 | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| 250 maximum where other supplies are/or can be made available | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| 1 000 reported as harmless | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

# TOTAL COLIFORMS

## Recommended Objectives

### REFERENCES

| Recommended Objectives | References |
|---|---|
| For drinking water only, not applicable to water source | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| Geometric mean not to exceed 20 000 organisms/100 mls | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| | 4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| 9 out of 10 samples should have less than 5 000 organisms/100 mls | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| Average not to exceed 1 000 organisms/ 100 mls. | 7. Water Quality Standards - B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

ANNEX B

WATER QUALITY OBJECTIVES FOR INDIGENOUS

BIOTA

## ANNEX B - WATER QUALITY OBJECTIVES

## FOR

## INDIGENOUS BIOTA

### Introduction

The following water quality objectives were prepared from a review of the current scientific literature. An Additional Reference section is included to accommodate titles of articles which were pertinent to the biological assessment of water quality standards but which were not available for review because of time and personnel constraints.

Shortage of time necessitated the use of several articles from which original references are listed individually in the Literature Cited section.

## TURBIDITY

### Recommendation

The turbidity shall not be caused to deviate more than ±20% of recorded values based on regression (p =0.05) of recorded stream flows versus turbidity requirements. These regressions should be calculated annually for each monitoring station within the basin until a sufficient data base is obtained.

### Rationale

Turbidity increases indicate an increase in the suspended solids load of the stream. These materials can damage the stream by causing silt build-ups on spawning and nursery grounds. Conversely, walleye (*Stizostedion vitreum vitreum*) require deep or turbid water during the day to protect the sensitive tapetum lucidum layer of the eye (33). The I.J.C. (6) recommends that the secchi disc value of the Great Lakes should not be decreased by more than 10%, but the standing water criterion cannot be directly applied to running water situations. Silt-carrying capacity of running water varies directly with water velocity. A correlation between historic stream flows and simultaneously measured turbidity should provide a historic basis with which to compare basin changes and stream loading. It was felt that changes of up to 20% from this historic background would not greatly harm the indigenous biota. This follows the Montana guidelines for BD2 (C-3) type streams (29).

## TEMPERATURE

### Recommendation

To protect walleye spawning and egg development and to protect invertebrates the water temperature from April 10 to May 15 shall not be increased above the natural water temperature. The water temperature must not be caused to exceed 30$^{\circ}$ C.

### Rationale

Walleye spawning is triggered by an increase in water temperature of 0.28$^{\circ}$ C per day (3). The optimum egg fertilization temp-

Temperature (Continued)

erature for walleye is reported at 6 - 12° C (4), although Brungs and Jones (7) show 8.9° C as maximum for walleye and pike spawning and development. The maximum growth of walleye juveniles and adults occurs at 22° C (4,5) and little or no growth occurs above 28.9° C (7). Walleye and perch will be lost from the reach if temperatures exceed 32° and fathead minnows if the temperature exceeds 34° C (23). The upper lethal temperatures for walleye acclimated at 8 - 26° C are 27 - 31° C (4). Mortalities occur when fry experience immediate temperature changes of +15° C and -5° C and juveniles changes of -17° C (4).

In summary, the spawning behaviour and eggs of walleye are sensitive to changes of temperature and to warm waters. The fry, juveniles and adults are quite tolerant of temperature changes but exhibit maximum growth at 22° C. Prolonged exposure to temperatures in excess of this will reduce the viability of the population.

With respect to the Poplar River there is a specific concern that a large slug of heated water, released from the reservoir during the walleye spawning and hatching period (April 10 to May 15) could elevate river water temperature disrupting spawning and causing egg mortality. The recommendations specifically address this possibility.

## ALUMINUM

### Recommendation

The concentration of dissolved aluminum shall not be caused to exceed 100 µg/L to protect aquatic life.

### Rationale

The toxicity of aluminum to aquatic organisms seems to depend on the concentration of soluble and colloidal aluminum. Metallic and insoluble forms have little effect (11). Very little information was obtained on specific toxicities. The $LC_{50}$ (3 week) for *Daphnia magna* is 1400 µg/L and the organism shows a 50% impairment in reproduction at 680 µg/L (1). Rainbow trout suffered

physiological and behavioral aberrations and mortality at 1500 μg/L dissolved Al (12) and unspecified concentrations of suspended Al caused "physiological and behavioral aberrations as well as acute mortality" (12). Suspended aluminum caused toxic effects at lower but unspecified quantities (12). Quantities of aluminum greater than 1500 μg/L constitute a hazard while minimum risk occurs at less than 200 μg/L (31). The objective, to protect all aquatic life, is listed by the I.J.C. (10) as 100 μg/L, based on trout growth responses. The E.P.A (30) support a similar objective.

## AMMONIA

### Recommendation

The concentration of un-ionized ammonia should not exceed 20 μg/L to protect aquatic life.

### Rationale

The toxicity of ammonia depends on the concentration of un-ionized ammonia ($NH_3$, $NH_4OH$) rather than ionized ammonia ($NH_4^+$) present (27). The $LC_{50}$ (96 hour) for perch is 350 μg/L (34 from 10). The recommended application factor for ammonia is 0.05 x $LC_{50}$ (96 hour) of the most sensitive organism (35 from 10). Applying this to the figure above for perch gives an objective of 17.5 μg/L. This compares favourably with the recommendation of the I.J.C. (10) of 20 μg/L of un-ionized ammonia to protect aquatic life including salmonids. The $LC_{50}$ (48 hour) for fathead minnows is 700 μg/L (36). While this figure is not directly comparable to the $LC_{50}$ (96 hour) given above for perch, the following conversion can be made. The I.J.C. (10) reports 500 μg/L and 250 μg/L as the $LC_{50}$ (48 hour) and $LC_{50}$ (96 hour) for rainbow trout (34, 37 from 10). The $LC_{50}$ (96 hour), then is about 50% of the $LC_{50}$ (48 hour) for that fish. If we apply this factor to the fathead minnow value listed above, the $LC_{50}$ (96 hour) for that fish becomes 350 μg/L, comparable with perch. The I.J.C. recommended level of 20 μg/L is based on the apparent threshold, for sub-lethal effects of ammonia on rainbow trout (38, 39 from 10). This value is close to those calculated for perch and fathead minnows and is suggested for the Poplar River system.

## ARSENIC

### Recommendation

The total concentration of arsenic should not exceed 100 μg/L to protect plant life.

### Rationale

Under conditions which might occur in aquatic systems, arsenic can exist in four oxidations states (+5, +3, 0, -3). Of these the +3 state is the most toxic, binding with the sulfhydryl group of cysteine and some enzymes. Arsenic has also been implicated as a carcinogen (28). It appears to be concentrated by some aquatic organisms but not amplified by the food chain (28).

Arsenic appears to have a low toxicity to aquatic animals. For *Daphnia magna* the $LC_{50}$ (3 week) is 2850 μg/L while 50% reproductive impairment occurs at 1400 μg/L (1). The catfish, *Ictalurus punctatus* bioaccumulates arsenic and is killed at concentrations of 2500 μg/L (25). Arsenic has historically been used as an aquatic herbicide (40 from 32). NAS/NAE (35 from 32) recommends long-term irrigation concentrations should not exceed 100 μg/L and this level should protect aquatic macrophytes.

## CADMIUM

### Recommendation

The total concentration of cadmium in hard waters should not exceed 1.2 μg/L to protect aquatic life.

### Rationale

Cadmium is toxic to a variety of aquatic organisms, depending in part, on water hardness. Crustaceans are very sensitive; *Gammarus sp.* $LC_{50}$ (96 hour) of 70 μg/L (41 from 6), *Daphnia magna* "safe level" in soft water (hardness 45.3 mg/L) of 0.17 μg/L (1). The maximum acceptable toxicant level (MATC) for fathead minnows in hard water (200 mg/L CaCO ) is 37 - 57 μg/L (42) although static bioassays have shown $LC_{50}$ (96 hour) as high as 32 000 μg/L for this species (42). The

chronic toxicity of cadmium was also confirmed for rainbow trout (43 from 21). Salmonids seem particularly susceptible to cadmium toxicity. The $TL_m$ (7 day) for rainbow trout is 8 μg/L (43 from 21) and brook trout exhibit testicular damage at 10 - 25 μg/L (as chloride) (45 from 21). Damage to egg and larval stages has been noted for fathead minnow embryos at 57 μg/L (42) and for rainbow trout, goldfish and narrow-mouthed toad eggs raised on sediments containing 100 - 1000 ppb of cadmium (14). The second example indicates regeneration of the toxin from sediment storage. This element can be concentrated by phytoplankton. Samples obtained off the California coast showed concentrations of up to 17.8 to 20.9 ppm (dry weight as opposed to background levels in the range of 1.0 to 5.8 ppm (dry weight) (20). *Selenastrum capricornutum*, however, showed no bioaccumulation within 5 days when grown in concentrations from 2 - 20 μg/L (13).

Photosynthetic rates were inhibited by 70% in the following species at the concentrations indicated: *Chlorella pyrenoidosa* at 100 μg/L, *Ankistrodesmus falcatus* (*Monoraphidium setiforme* (Nyg.) comb. nov.) and *Chlorella vulgaris* at 1000 μg/L (47 from 6). *Selenastrum capricornutum* showed slight inhibition at 50 μg/L and complete growth inhibition at 80 μg/L (47 from 6). *Najas guadalupensis* a macrophyte, showed reduction in chlorophyll at 7 μg/L and "severe effects" at 90 μg/L (49 from 6).

The E.P.A. (32) recommends a maximum concentration of 12 μg/L to protect aquatic life, except cladocerans and salmonids, in hard water systems, and 1.2 μg/L if all species are to be included. Because of the phytotoxicity of cadmium it is suggested that this second standard be accepted.

## CHROMIUM

### Recommendation

The total concentration should not exceed 100 μg/L to protect aquatic life, especially the diatom *Nitzschia palea*.

### Rationale

Chromium is toxic to *Daphnia magna* with an $LC_{50}$ (3 week) of 2000 μg/L, 50% reproductive impairment at 600 μg/L and a "safe level" of $CrCl_3$ of 330 μg/L (1). The MATC for fathead minnows lies

in the range 1000 to 3950 μg/L (2). The $LC_{50}$ (96 hour) for this fish is 27 300 μg/L for hexavalent chromium and 27 000 μg/L for trivalent chromium with water hardness of 360 μg/L $CaCO_3$ (50 from 32). The diatom *Nitzschia palea* showed a 50% reduction in photosynthesis at 208 - 650 μg/L and a slowing of the growth rate at 150 μg/L (51 from 6). Patrick's (51) data was probably derived from softer water than that of the Poplar River. In view of this the E.P.A. recommednation of 100 μg/L seems adequate to protect aquatic life in the Poplar River system.

## COPPER

### Recommendation

Concentrations of dissolved copper should not exceed 5 μg/L to protect aquatic life, especially amphipods.

### Rationale

The toxicity to *Daphnia magna* depends on the concentration of $Cu^{+2}$ (cupric) and $Cu(OH)_n$ (copper hydroxy) ions and not on $CuCO_3$ and other complexes (16). The $LC_{50}$ (3 week) for *Daphnia magna* is 44 μg/L, 50% reproductive impairment occurs at 35 μg/L and the "safe level" is 22 μg/L (1). The safe level for the fathead minnow ranges from 10.6 to 14.5 μg/L depending on water hardness (52, 53 from 1). The MATC for the fathead minnow is listed at 10.6 - 18.4 μg/L (2). *Gammarus pseudolimnaeus* is even more susceptible with the safe level of 4.6 - 8.0 μg/L when the water hardness is 45 μg/L CaCO (44 from 1). E.P.A. recommends a limit of 0.1 times the $LC_{50}$ (96 hour) of the most sensitive species (32). Without this information we have chosen the lower safe level of *G. pseudolimnaeus*. *Gammarus sp.* is present in the basin and forms an important fish food and link in the ecosystem.

## IRON

### Recommendation

The concentration of dissolved iron should not exceed 600 μg/L and of $Fe(OH)_3$ 3000 μg/L to protect invertebrates.

Iron (Continued)

## Rationale

The $LC_{50}$ (3 week) for *Daphnia magna* is 5900 μg/L and 50% reproductive impairment occurs at 5200 μg/L dissolved iron (1). Iron hydroxide ($Fe(OH)_3$) caused mortality to and decreased the growth rate of fathead minnows at 12 000 - 50 000 μg/L (26). The maximum tolerable level for *Gammarus minus* is 3000 μg/L as hydroxide but concentrations of 20 000 μg/L had little effect on the stonefly *Cheumatopsyche* (26).

The criterion for dissolved iron was derived by taking 10% of the $LC_{50}$ (3 week) for *Daphnia magna* and rounding this number to 600 μg/L. The concentration for $Fe(OH)_3$ of 3000 μg/L is the maximum tolerable level for *Gammarus minus* and is lower than the level at which fathead minnow mortality occurs.

# LEAD

## Recommendation

The concentration of total lead should not exceed 30 μg/L to protect aquatic life.

## Rationale

The $LC_{50}$ (3 week) for *Daphnia magna* is 300 μg/L and 50% reproductive impairment occurs at 100 μg/L and 16% reproductive impairment at 30 μg/L (1). The E.P.A. recommends that a hazard exists at concentrations above 50 μg/L and that concentrations less than 10 μg/L minimize risk (31). The toxicity of total lead varies with water hardness. In the Poplar River system we suggest that 10% of the $LC_{50}$ (3 week) of *D. magna* should protect aquatic life. This figure compares with the level causing 16% reproductive impairment of *D. magna*.

## MERCURY

### Recommendation

To protect aquatic life and fish-eating birds and mammals:

(a) Total mercury from a filtered sample should not exceed 0.2 ug/L

(b) Total mercury content of fish should not exceed 0.5 ug/Kg fresh weight of whole fish; and

(c) Methyl mercury in water should not exceed 0.05 ug/L.

### Rationale

The discussion of mercury objectives by the I.J.C. (6) is accepted as valid for the Poplar River system. In addition it is noted that egg mortalities and teratogenesis occur if the eggs of rainbow trout , goldfish and narrow-mouthed toads are hatched in sediments enriched with 100 - 1000 μg/L mercury (14). The $LC_{50}$ (96 hour) for *Penaeus setiferus* (white shrimp) is 17 μg/L while no toxic effect is shown at 0.5 - 1.0 μg/L (17). Methyl mercury seems much more toxic to aquatic life. *Daphnia magna* shows significant reproductive impairment at 0.04 μg/L (54 from 32) and the MATC for fathead minnows is 0.07 - 0.13 μg/L (2).

## NITRATE

### Recommendation

Nitrate concentrations should not be increased more than 10 percent of the historic seasonal values to reduce the potential of eutrophication.

### Rationale

There is a lack of good guidelines to judge the effects of nutrient increases on specific organisms in a eutrophic ecosystem. It was decided that a 10% fluctuation from the seasonal norm could be accepted and would probably cause little long-term effect.

## OXYGEN

### Recommendation

The oxygen concentration should not be less than 5.0 μg/L during the period of spawning and egg hatch, from April 10 to May 15 to protect fish, fish eggs and fish larvae. During the rest of the year the concentration should exceed 4 μg/L.

### Rationale

Davis (8) recommends 4.0 μg/L of oxygen as capable of supporting a population of mixed freshwater fish, excluding salmonids. This represents a range of 47 - 48% saturation for temperatures from 0 - 25$^{o}$ C. The I.J.C. (9) discusses this subject extensively. The increase in oxygen concentration to the level recommended by the E. P.A. (32) during fish spawning and incubation periods should improve hatch success.

## PHOSPHORUS

### Recommendation

Phosphorus concentrations should not be increased more than 10 percent of the historic seasonal values to reduce the potential of eutrophication.

### Rationale

The same rationale as offered for the limits on nitrate changes.

## SELENIUM

### Recommendation

No information was available on which a criterion could be based. No criterion is offered.

## Discussion

The I.J.C. recommends that the concentration should not exceed 2 percent of the $LC_{50}$ (96 hour) of the most sensitive resident species. When such information becomes available a limit may be placed on selenium.

*Phormidium luridum* (blue-green algae) showed cell degeneration and lysis at concentrations of 0.00001 M of selenite ($SeO_3$) which is approximately 1270 μg/L.

# TOTAL DISSOLVED SOLIDS (TDS)

## Recommendation

The TDS should not exceed 2500 μg/L to preserve walleye populations.

## Rationale

The $LC_{50}$ (96 hour) is 4 500 μg/L for *Daphnia sp.* and 8 800 μg/L for walleye (6). The recommended application factors are 0.3 to 0.5 times the $LC_{50}$ (96 hour) which gives a limit for walleye of 2 640 to 4 400 μg/L. We recommend the limit of 2 500 μg/L as probably capable of protecting the walleye population including the eggs and larvae.

# ZINC

## Recommendation

The concentration of zinc in unfiltered water should not exceed 30 μg/L to protect aquatic life.

## Rationale

The $LC_{50}$ (3 week) for *Daphnia magna* is 158 ug/L and 50% reproductive impairment occurs at 102 ug/L (1). The $LC_{50}$ (64 hour) is 150 ug/L (immobilization) (55 from 6). THE MATC for fathead minnows is 78 - 145 ug/L in soft water (2) and 30 - 180 ug/L (54 from 2). The safe level for fathead minnows is 27.3 ug/L in hard water when copper and cadmium are present (58 from 6). The presence of various concentrations of these other elements appears to increase zinc toxicity. The concentrations of zinc causing sublethal harm to aquatic biota do not appear to vary with hardness or alkalinity (6). Rainbow trout, goldfish and narrow-mouthed toad eggs showed mortality and teratogenesis when incubated on sediments containing 1000 - 10 000 ug/L of added zinc (14). Carp (*Cyprinus carpio*) yearlings were not killed at concentrations of 15 000 ug/L (19). Some plants are affected. *Oedogonium sp.*, *Cladophora glomerata* and *Selenastrum capricornutum* are inhibited at 220, 240 and 700 ug/L (56 and 57 from 6). Concentrations of 1000 ug/L are toxic to *Cladophora sp.* (59 from 24) but *C. glomerata* is recorded as growing in hardwater (90 mg/L Ca, 10 mg/L Mg) streams with 170 ug/L dissolved zinc and greater than 700 ug/g in the sediments (24).

Assuming that zinc toxicity is not greatly reduced by water hardness (6) we must accept that MATC for fathead minnows (30 ug/L) as our objective.

# pH

## Recommendation

The pH should not be caused to exceed the range of from 6.5 to 9.0.

## Rationale

Through lack of critical data on which to base a recommendation we accept the discussion and recommendation of the I.J.C. (6).

SUMMARY TABLE

Biological water quality objectives for the Poplar River system.

| Parameter | Concentration | To Protect | Reference |
|---|---|---|---|
| Turbidity | ±20% historic[1] values | walleye | |
| Temperature | (see text) | walleye | |
| Aluminum | 100 µg/L (dissolved $^{+}OH$) | aquatic life | 10 |
| Ammonia | 20 µg/L (un-ionized) | fathead minnows | 10, 32 |
| Arsenic | 100 µg/L (total) | plants | 32 |
| Cadmium | 1.2 µg/L (total) | plants, fish | 47, 32 |
| Chromium | 100 µg/L (total) | (diatom) | 51 |
| Copper | 5 µg/L (dissolved) | | 44 |
| Iron | 600 µg/L (dissolved) | | 1 |
| | 3000 µg/L (particulate) | | 26 |
| Lead | 30 µg/L (total) | | 1 |
| Mercury | 0.2 µg/L (dissolved) | | |
| | 0.05 µg/L (dissolved methyl) | | 54 |
| | 0.5 µg/kg (fresh wt. of fish) | fish-eating animals | |
| Nitrate | ±10% historic values | | |
| Dissolved Oxygen | 5000 µg/L April 10-May 15<br>4000 µg/L remainder of year | walleye | 32, 8 |
| Phosphate | ±10% historic values | | |
| Selenium | no information | | |
| Total dissolved solids | 2500 µg/L | walleye | 6 |
| Zinc | 30 µg/L (total) | fathead minnows | 6 |
| pH | 6.5 - 9.0 | aquatic life | 6 |

[1] Based on a regression (p =0.05) of recorded stream flows versus turbidity.

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# ANNEX C

# WATER QUALITY OBJECTIVES FOR AGRICULTURAL WATER SUPPLY

## ANNEX C

## WATER QUALITY OBJECTIVES FOR AGRICULTURAL WATER SUPPLY

### Introduction

The following information represents tentative technical recommendations concerning those parameters which are considered relevant to the protection of agricultural uses in the Poplar River Basin. The recommendations are based on a detailed literature review of current water quality criteria data. The initial Table summarizes the recommendations and the remainder of the index contains the background material from which the recommendations were drawn.

SUMMARY OF RECOMMENDATIONS

IRRIGATION - WILDLIFE USAGE

POPLAR RIVER BASIN

| Parameter | Long-Term Limit | Short-Term Limit 90-days | Comments |
|---|---|---|---|
| Total Dissolved Solids | 1 000 mg/l | 1 500 mg/l | Control is irrigation usage. |
| Sodium Adsorption Ratio | 10 | --- | Assumes non-sensitive crops in Basin. |
| Boron | 5.0 mg/l | 8.0 mg/l | Assumes non-sensitive crops in Basin. |
| Conductivity | --- | --- | Closely related to Total Dissolved Solids. |
| Sodium | --- | --- | Limit not needed in view of Sodium Adsorption Ratio controls. |
| Chlorides | --- | --- | Limit not needed in view of Total Dissolved Solids controls. |
| Sulphate | 1 000 mg/l | --- | Based on livestock pathology; Total Dissolved Solids will control. |
| Cobalt, Copper, Selenium, and Molybdenum | --- | --- | Not considered a problem at this time because of low background levels. |

## TENTATIVE RECOMMENDATIONS - IRRIGATION

### Total Dissolved Solids

It is recommended that 1 000 mg/L be the limit on a long-term basis with 1 500 mg/L being acceptable during shorter time increments (less than three months).

Presently, 1 000 mg/L is exceeded in the Poplar River during the summer. The recommended limits will protect all but the most sensitive crops such as citrus which are obviously not expected to be grown in the basin. The 1 500 mg/L level will also not have an adverse impact provided its duration is only for a few months.

### Sodium Adsorption Ratio (SAR)

Generally, for non-sensitive crops, problems with the SAR do not begin until the value significantly exceeds eight. A value of ten is recommended in the basin in recognition of the historical values and the anticipated crops which may be grown in the future. Crops which are not considered sensitive to the SAR are potatoes, corn, peas, carrots, and most vegetables along with wheat, oats, and alfalfa. Radishes, celery, and green beans are more sensitive to the SAR.

### Boron

Most of the cited literature indicates that values up to 4 mg/L boron do not cause significant problems to non-sensitive crops, such as alfalfa and potatoes. However, recent re-analysis of past boron data by Dr. Jim Rhoades of the U.S. Salinity Laboratory, Riverside, California has revealed several discrepancies. One of the original pieces of research by Eaton (1944) showed that alfalfa can tolerate up to 15 mg/L boron, whereas, barley is very sensitive to boron and will reduce grain yields by approximately 5, 15 and 25 percent at 1.0, 3.0 and 5.0 mg/L boron, respectively.

The boron concentrations in the waters of the Poplar River basin under natural conditions range between $<$ 1.0 and 5.0 mg/L with an average of near 2.0 mg/L. Since alfalfa is the major crop grown under irrigation in the basin and since barley does not play a significant role in crop production under irrigation (105 acres of a total 1063 acres irrigated from the East Poplar and Poplar Rivers), it is recommended that the long-term mean value for boron be 5.0 mg/L with values as high as 8.0 mg/L being permissible for short periods of time (3 months or less) during the irrigation season.

## Electrical Conductivity

Electrical Conductivity is closely related to Total Dissolved Solids. No recommendation is, therefore, considered necessary.

## Sodium

Problems due to high Sodium content are directly related to the calcium and magnesium content of water which is incorporated in the SAR. No recommendation is made for Sodium in view of the recommended limit for SAR.

## Chloride

No limitation is recommended for Chloride because of its close relationship to Total Dissolved Solids.

# TENTATIVE RECOMMENDATIONS - LIVESTOCK

## Sulfate

Pathological problems appear to begin above 2 000 mg/L. Therefore, it is recommended that the value be set at 1 000 mg/L. The suggested Total Dissolved Solids criteria of 1 000 - 1 500 mg/L will also adequately control this parameter.

## Cobalt

Poplar River values appear to be 0.01 mg/L and values of 1.0 mg/L are acceptable for livestock. No recommendation is considered necessary at this time.

## Copper

Historical values are low (0.05) and livestock can tolerate concentrations in the neighborhood of 1.0 mg/L. No recommendation is considered necessary at this time.

## Selenium

Historical values in the Poplar River are less than 0.01 mg/L for Total Selenium. Literature indicates that values in excess of 0.1 mg/L are not troublesome. Water Quality Criteria - 1972 recommends a value of 0.05 mg/L which seems conservative. If a value were selected, 0.05 mg/L is considered appropriate, but no recommendation is considered necessary at this time.

## Molybdenum

The results of a fairly substantial research project of the University of Colorado indicates that 0.15 mg/L is satisfactory for cattle consumption. Values in the Poplar River are significantly less than this. A Total Molybdenum value of 0.15 mg/L would be an adequate protective level but no recommendation is considered necessary at this time.

## Total Dissolved Solids

Water Quality Criteria - 1972 states that values less than 3 000 mg/L "should be satisfactory for livestock under almost any circumstance". Furthermore, "some minor physiological upset may result

from salinities near the limit (3 000 mg/L) but economical losses should rarely, if ever, result from their use". Cattle routinely consume water in excess of 5 000 mg/L in Wyoming. A limit of 3 000 mg/L, therefore, appears appropriate for livestock consumption and is, therefore, recommended.

## SUMMARY OF REFERENCES ON IRRIGATION WATER QUALITY

### Total Dissolved Solids

| Use Quality Objectives | References |
|---|---|
| (1) any TDS limits used in classifying the salinity hazard of waters are somewhat arbitrary. | Water Quality Criteria 1972 NAS-NAE, Washington, D.C. p. 335. |
| (2) the hazard is not related to TDS but also the individual ions involved. | |
| (3) no exact hazard can be assessed unless the soil, crop, and acceptable yield reductions are known. | |
| Recommended Guidelines for Salinity in Irrigation Water (mg/L): | |
| No detrimental effect noticed - 500 | Quality Water Criteria U.S. EPA. 1976. |
| May have detrimental effects on sensitive crops - 500 - 1000 | Characteristics and Pollution Problems of Irrigation |
| May have adverse effects on crops; requires careful management - 1000-2000.<br>Used for tolerant plants on permeable soils with careful management - 2000-5000. | Return Flow. U.S. Dept. Interior, 1969, p. 46. |
| Dissolved Solids in Rivers in Arid and Semiarid United States (mg/L) | |
| (Note: these rivers are used for irrigation) | Water Quality Criteria 1972 NAS-NAE, Washington, D.C. p. 333. |

| | |
|---|---|
| Columbia River Basin | - 100 - 300 |
| Northern California | - 100 - 700 |
| Southern California | - 100 - 2000 |
| Colorado River Basin | - 100 - 2500 |
| Rio Grande Basin | - 100 - 2000 |
| Pecos River Basin | - 100 - 3000 |
| Western Gulf of Mexico Basin | - 100 - 3000 |

| | | |
|---|---|---|
| Red River Basin | - 100 - 2500 | |
| Arkansas River Basin | - 100 - 2000 | |
| Platte River Basin | - 100 - 2000 | |
| Upper Missouri River Basin | - 100 - 2000 | |

Dissolved Solids

| | | |
|---|---|---|
| Satisfactory<br>Poor Quality | 100 - 1500<br>1500 - 3000 | Water Quality Objectives. 1975. Saskatchewan |
| long term irrigation | 500 | Water Quality Criteria. 1976. Montana |
| permissible<br>desirable | 500<br>200 | Guidelines and Criteria for Water Quality Management in Ontario. 1973. |
| Irrigation waters less than 700 - 800 are not expected to create serious problems in Manitoba. | | Proposed Specific Water Quality Objectives for the Souris, Red, and Roseau Rivers at the International Boundary. 1977. |

## Yield Reductions and T.D.S.

It is known that as the salt content of applied irrigation water increases then at some point a yield decrease will result. The amount and rate of yield decrease depends primarily on the leaching fraction. Bernstein and Francois (1973) showed that alfalfa irrigated at low leaching fractions ranging from 3.1 to 12.5 percent with water that had an electrical conductivity (EC) of 2 mmhos/cm (T.D.S. $\triangleq$ 1340 mg/L) consistently yielded 10 percent less than water that had an E.C. of 1 mmho/cm. Bower, et al (1969) showed that irrigation waters having E.C.'s of 2 and 4 mmhos/cm and leaching fractions of 0.13 and 0.29 percent, respectively, prevented yield decreases of more than 10 percent.

In an attempt to relate irrigation water salt content, leaching fraction and yield reduction, Jome and Nicholaichuk (1979) developed an equation relating the steady-state salinity profile to the salinity of irrigation water ($EC_{iw}$) and the leaching fraction (LF) based on steady downward flow conditons. The equation was given as:

$$EC_{sw} = \frac{EC_{iw}}{1 - (1-LF)\frac{x}{d}(2 - \frac{x}{d})}$$

where $EC_{sw}$ is the calculated E.C. of the soil solution, d is the depth of the root zone and x any depth within the root zone.

The deviation of the equation, similar to that used by Raal (1974) was based on the following assumption:

(1) steady-state flow water condition;
(2) no chemical precipitation or dissolution of salts in soils;
(3) 40 percent of crop water uptake from upper quarter of root zone, 30 percent from the next quarter, 20 percent from the third quarter, and 10 percent from the lower quarter;
(4) E.C. of the soil saturated paste extract is equivalent to approximately one-half of the calculated soil water $EC_{sw}$ at field capacity.

The predicted model results were compared with experimental results obtained by Bower, et al (1969) and with sewage effluent irrigation results obtained at Swift Current (Jome, et al, 1979) and the resulting calculated curves agreed very well with measured distributions. The results clearly indicated that at steady-state conditions, salinity profiles increase gradually from a level near the surface; they are controlled by the salinity of the irrigation water to a level near the bottom of the root zone, and are determined primarily by the leaching fraction.

In order to calculate relative yield or yield reduction, the soil paste EC values predicted by the model for the upper, second, third and bottom quarters of the soil profile were weighted by plant water consumption of 40, 30, 20 and 10 percent, respectively. These values were used to calculate a mean $EC_e$ for the soil profile. In making this calculation, the soil paste EC value in the first layer was increased by 1.6 times to account for salt retention by evaporation. The resulting average soil profile ECe value was then compared to the results presented by Ayers and Westcot (1976) for soil EC versus alfalfa yield reduction. The calculated alfalfa yield reductions for various E.C.'s and leaching fractions were determined as:

Percent Yield Reducation of Alfalfa*

| Irrigation Water E.C. (mmhos/cm) | Leaching Fraction (Percent) 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| 1.0 (TDS = 670 mg/L) | 0 | 0 | 0 | 0 |
| 1.5 (TDS = 1005 mg/L) | 3 | 0 | 0 | 0 |
| 2.0 (TDS = 1340 mg/L) | 10 | 4 | 1 | 0 |

* E.C. values given do not assume any dilution effect due to rainfall as would occur under field conditions.

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## Sodium Adsorption Ratio (SAR)

| Use Quality Objectives | References |
|---|---|
| $$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$ where Na, Ca, Mg units in meq/l | Water Quality Criteria 1972. NAS-NAE, Washington, D.C. p. 330-331 |

"To reduce the sodium hazard in irrigation water for a specific crop, it is recommended that the SAR value be within the tolerance limits determined by the U.S. Soil Salinity Laboratory Staff."

| SAR Value of Irrigation Water | Estimated ESP Value of Soil | |
|---|---|---|
| 1 | 0.3 | |
| 2 | 1.6 | Sensitive |
| 3 | 3.1 | Crops |
| 4 | 4.5 | |
| 5 | 5.6 | |
| 6 | 7.1 | |
| 7 | 8.2 | |
| 8 | 9.5 | General |
| 9 | 10.7 | Crops and |
| 10 | 11.9 | Forages |
| 12 | 14.2 | |
| 14 | 16.2 | |
| 16 | 18.4 | |
| 18 | 20.1 | |
| 20 | 22.4 | |
| 24 | 25.4 | |
| 30 | 30.2 | |

Sensitve fruits 4 — Quality Criteria for Water, U.S. EPA. 1976.

General crops and forages 8 - 18

Soils - an exchangeable-sodium percentage (ESP) of 10 - 15% is considered high if swelling clay minerals are present

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long term irrigation 8 — Water Quality Criteria. 1976. Montana.

Toxicity from root adsorption

| | | |
|---|---|---|
| no problem<br>increasing problems<br>severe problems<br>(SAR values were modified) | 3<br>3 - 9<br>9 | Quality of Water for Irrigation. 1977. J. Irrig. and Drainage. |
| permissible<br>desirable | 6<br>4 | Guidelines and Criteria for Water Quality Management in Ontario. 1973. |
| acceptable<br>desirable (leaf burn)<br>less sensitive crops | 6<br>4<br>6 - 7 | Proposed Specific Water Quality Objectives for the Souris, Red and Roseau Rivers at the International Boundary. 1977. |

## Sodium

| Use Quality Objectives (mg/l) | References |
|---|---|
| -high concentrations of sodium can affect soil structure and permeability. | Water Quality Criteria 1972. NAS-NAE, Washington, D.C. p. 329-330. |
| -leaf burn in almonds, avocados, and stone fruits grown in culture solutions (root absorption). | |
| -soil ESP values greater than 10 - 15% considered excessive where high percentage of swelling clay minerals (montmorillonite) are present. | |
| -fair crop growth of alfalfa, cotton and even olives in soils of San Joaquin Valley (California) with ESP values ranging from 60 - 70%. | |
| -"To reduce the sodium hazard in irrigation water for a specific crop, it is recommended that the SAR value be within the tolerance limits determined by the U.S. Soil Salinity Laboratory Staff". | |

| | | |
|---|---|---|
| Satisfactory | 300 | Water Quality Objectives, Saskatchewan 1975. |
| Poor quality | 300 - 500 | |
| Surface waters (between of cations) | 30 - 75% | |

---

Toxicity from foliar adsorption

| | | |
|---|---|---|
| no problem | 69 | Quality Water for Irrigation 1977. J. Irrig. and Drainage. |
| increasing problems | 70 | |
| severe problems | -- | |

## Boron

| Use Quality Objectives | References |
|---|---|
| -essential element in low concentrations<br><br>-accumulation of boron in soils is an adsorption process, and before soluble levels of 1 or 2 mg/L can be found in the soil solution, the adsorptive capacity must be saturated.<br><br>-"From the extensive work on citrus, one of the most sensitive crops, the maximum concentration of 0.75 mg B/L for use on sensitive crops on all soils seems justified. Recommended maximum concentrations for semitolerant and tolerant plants are considered to be 1 and 2 mg/L, respectively".<br><br>-"For neutral and alkaline fine textured soils the recommended maximum concentration of boron in irrigation water used for a 20-year period on sensitive crops is 2.0 mg/L. With tolerant plants or for shorter periods of time higher boron concentrations are acceptable". | Water Quality Criteria 1972. NAS-NAE, Washington, D.C. p. 341 |

---

| | | |
|---|---|---|
| Sensitive plants (citrus) | 0.75 | Quality Criteria for Water. U.S. EPA. 1976. |
| Neutral-alkaline soils with high adsorption capacity (sensitive plants) | 2.0 | |

---

| | | |
|---|---|---|
| Relative tolerance of plants to Boron in irrigation water | | Characteristics and Pollution Problems of Return Flow. U.S. Dept. Interior, 1969. |
| asparagus, sugar beet, garden beet, alfalfa, broadbean, onion turnip, cabbage, lettuce, carrot, sunflower, potato, tomato, radish, barley, wheat. | 4.0 - 2.0 | |
| corn, sorghum, oats, pumpkins, bell peppers, sweet potato, lima beans. | 2.0 - 1.0 | |
| mainly fruit trees | 1.0 - 0.3 | |
| Surface Water Quality Objective | 0.5 | Water Quality Objectives, 1975. Saskatchewan. |
| long term irrigation | 0.75 | Water Quality Criteria. 1976 Montana. |
| Toxicity from root adsorption — none | 0.5 | Quality of Water for Irrigation 1977. J. Irrig. and Drainage Div. |
| increasing problems | 0.5 - 2.0 | |
| severe problems | 2.0 | |
| permissible<br>desirable | 0.5<br>0.3 | Guidelines and Criteria for Water Quality Management in Ontario. 1973. |
| acceptable<br>desirable | 0.75<br>0.50 | Proposed Specific Water Quality Objectives for the Souris, Red, and Roseau Rivers at the International Boundary. 1977. |

Recent re-analysis of the past boron data by Rhoades has shown several discrepancies in previous boron criteria. A re-examination of the boron work conducted by Eaton (1944) relating to applied boron concentrations to yield reduction has shown the following results:

Rhoades, J., 1979. Personal Communication. U.S. Salinity Laboratory, Riverside, California.

Eaton, F.M., 1944. Deficiency toxicity and accumulation of boron in plants. J. Agric. Res. 69: 237-277.

Relative Crop Yields (Percent)*

| Crop | Boron Concentration (mg/L)† | | | | | |
|---|---|---|---|---|---|---|
| | Trace | 1.0 | 5.0 | 10.0 | 15.0 | 20.0 |
| Alfalfa | 100 | 110 | 110 | 109 | 105 | 59 |
| Barley grain | 100 | 88 | 64 | 63 | 21 | 19 |
| Barley hay | 100 | 85 | 61 | 57 | 35 | 23 |
| Oat grain | 100 | 73 | 142 | 78 | 51 | 20 |
| Oat hay | 100 | 112 | 117 | 90 | 68 | 34 |
| Sweet clover | 100 | 163 | 215 | 165 | 159 | 170 |
| Potato | 100 | 135 | 120 | 101 | 83 | 30 |

* All yields expressed as a percentage relative to the trace boron concentration.

† The boron concentrations do not account for rainfall dilution as would occur in the field.

Alfalfa shows a large degree of tolerance with no yield decreases up to 15 mg/L boron. Barley is very sensitive to boron showing yield decreases even at 1.0 mg/L boron.

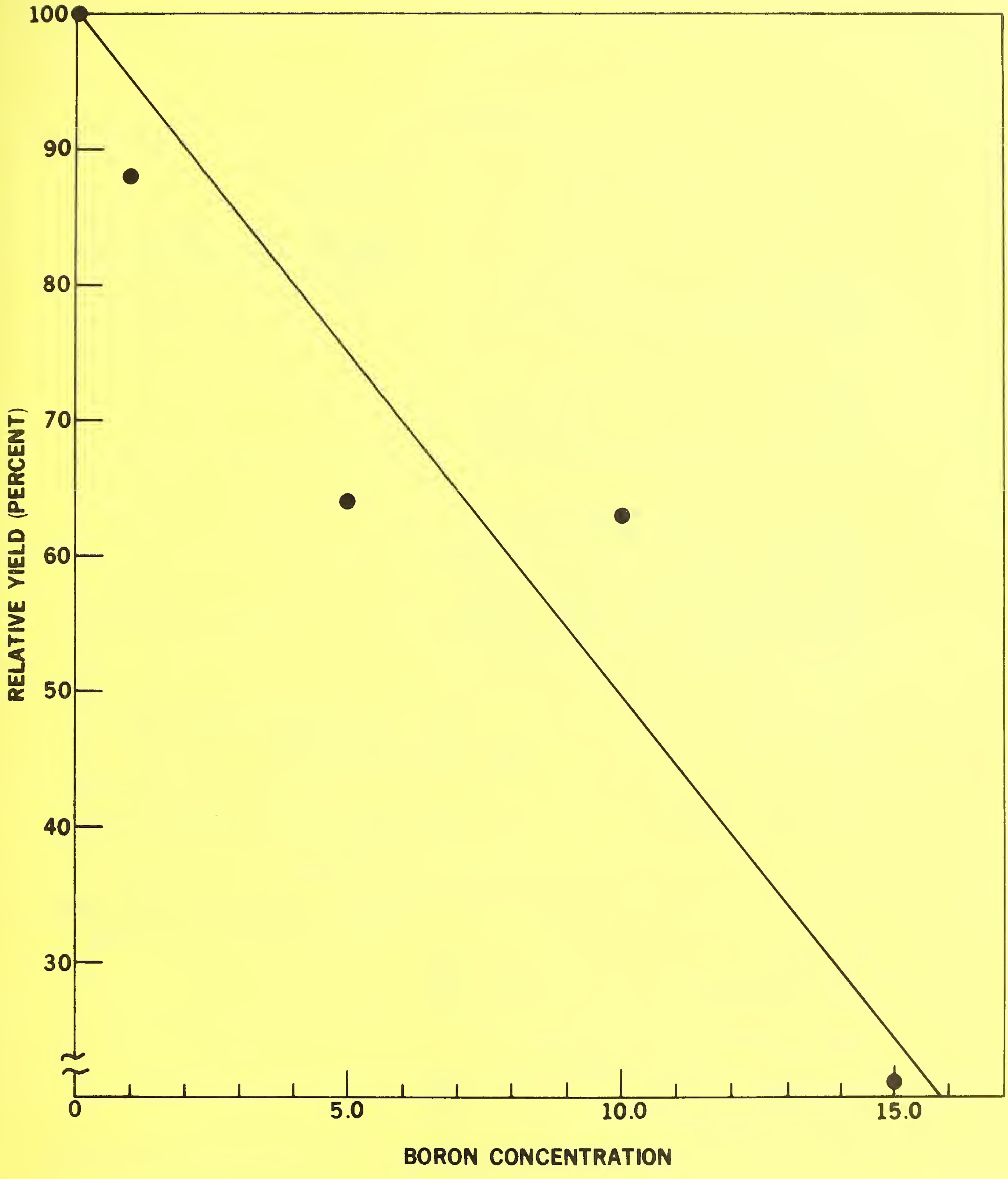


**Figure C-1 Relative yield of Barley with increasing Boron concentration plotted from results of Eaton, 1944.**

## Chlorides

| Use Quality Objectives (mg/L) | | References |
|---|---|---|
| -not generally toxic to crops<br><br>-values up to 710 can be used for sensitive fruit crops depending upon environmental conditions, crop, and irrigation management.<br><br>-sprinkler irrigation - foliar adsorption - values as low as 106 have caused problems on citrus, stone fruits, and almonds (avoid by night or more rapid rates).<br><br>-"Permissible chloride concentrations depend upon type of crop, environmental conditions and management practices. A single value cannot be given, and no limits should be established, because detrimental effects from salinity per se ordinarily detercrop growth first". | | Water Quality Criteria, 1972. NAS-NAE, Washington, D.C. p. 328-329. |
| Satisfactory | 250 | Water Quality Objectives. Saskatchewan. 1975. |
| Poor quality | 250 - 500 | |
| long term irrigation | 100 | Water Quality Criteria. 1976 Montana. |
| -Toxicity from root adsorption | | Quality of Water for Irrigation. 1977. J. Irrig. and Drainage. |
| no problems | 142 | |
| increasing problems | 142 - 355 | |
| severe problems | 355 | |
| -Toxicity from foliar adsorption | | |
| no problems | 106 | |
| increasing problems | 107 | |
| severe problems | - | |

| | | |
|---|---|---|
| permissible<br>desirable | 150<br>70 | Guidelines and Criteria for Water Quality Management in Ontario. 1973. |
| Acceptable - leaf burn from sprinklers, but higher concentration is permissible where surface irrigation is applied. | 150 | Proposed Specific Water Quality Objectives for Souris, Red, and Roseau Rivers at the International Boundary, 1977. |

## Electrical Conductivity

| Use Quality Objectives (mmhos/cm) | | References |
|---|---|---|
| long term irrigation | 0.75 | Water Quality Criteria. 1976. Montana. |
| no problem<br>increasing problems<br>severe problems | 0.75<br>0.75 - 3.0<br>3.0 | Quality of Water for Irrigation 1977. J. Irrig. and Drainage. |
| No detrimental effects | 0.75 | Water Quality Criteria 1972. NAS-NAE, Washington, D.C. |
| Detrimental to sensitive crops | 0.75 - 1.50 | |
| Adverse effect on many crops; requires careful management | 1.50 - 3.00 | |
| Used for tolerant plants with careful management | 3.00 - 7.00 | |

## SUMMARY OF REFERENCES ON LIVESTOCK USAGE

### Sulphate

| Use Quality Objectives (mg/L) | References - Comments |
|---|---|
| 1,000 - 2,000 | Australian Water Quality Criteria<br>Water Quality Criteria - 1968<br>McKee and Wolf, 1963<br><br>There are no recommendations in "Water Quality Criteria - 1972" or in "Quality Criteria for Water - 1976"<br><br>Both McKee and Wolf and the authors of Water Quality Criteria - 1968 cite "personal communication" with an individual named G.J. Stander in citing the 1 000 mg/L limit. There seems to be little doubt that pathological problems begin when Sulfate levels begin to significantly exceed 2 000 mg/L. |

### Cobalt

| Use Quality Objectives (mg/L) | Reference - Comments |
|---|---|
| 1.0 - See Comments | Cobalt is a necessary nutrient and in an element contained in Vitamin $B_{12}$.<br><br>Clarke and Clarke, Veterinary Toxicology, 1975, cite references showing toxicity to various animals such as greater than 1.0 mg/kg for calves and greater than 160 mg/kg for sheep.<br><br>Water Quality Criteria - 1968, states that if a problem occurs, it usually is in the feed .<br><br>No recommendations in Quality Criteria for Water, 1976.<br><br>Water Quality Criteria, 1972, recommends 1.0 mg/L which offers a "satisfactory margin of safety". |

## Copper

| Use Quality Objectives (mg/L) | References - Comments |
|---|---|
| 0.5 - 2.0 | Copper is an essential element but is also toxic to livestock with sheep being the most vulnerable. Toxic doses of Copper Sulphate were observed as follows:<br><br>25 - 50 mg/kg - lambs<br>130 mg/kg -sheep<br>200 mg/kg - cows<br><br>Toxic levels in the "diet" of sheep and lambs ranged from 9 - 20 mg/L. Treatment for Copper poisoning involves the administration of 50 - 500 mg of Ammonium Molybdate, reference: Clarke and Clarke, Veterinary Toxicology.<br><br>McKee and Wolf and Water Quality Criteria - 1968 both cite a 1931 study on turkeys showing they could safely drink water of less than 100 mg/L.<br><br>Water Quality Criteria - 1972 recommends a value of 0.5 mg/L with a statement that "very few natural waters should fail to meet this".<br><br>Saskatchewan objectives and proposed Montana WQS involve values less than 0.1 mg/L but it is speculated that this is based more on aquatic toxicity than livestock.<br><br>Quality Criteria for Water - 1976 has no livestock recommendation.<br><br>Australia Criteria can run up to 2.0 mg/L for livestock. |

## Selenium

| Use Quality Objectives | References - Comments |
| --- | --- |
| See Comments. Questionable if needed for livestock. | Wildlife poisoning by Selenium is common on the Western range and it is known as Alkali Disease. Cause of the disease is almost universally the consumption of plants from soils with a high Selenium content.<br><br>Clarke and Clarke, Veterinary Toxicology, state that Selenium content in food as low as 1 mg/L may be toxic but there is no mention of Selenium poisoning by water.<br><br>McKee and Wolf cite a couple of references showing that Selenium is not toxic to cattle with concentrations in water of 0.4 - 0.5 mg/L.<br><br>Water with high concentrations of Selenium is unpalatable to livestock according to Water Quality Criteria - 1968.<br><br>Water Quality Criteria - 1972 states, "to date, no substantial cases of Selenium poisoning in livestock by waters have been reported although some spring and irrigation waters have been found to contain over 1 mg/L of the element". The references cited are all old, however. 0.1 - 0.2 Quality Criteria - 1972 still recommends a limit of 0.05 mg/L despite the above. |

## Molybdenum

| Use Quality Objectives (mg/L) | References - Comments |
| --- | --- |
| 0. 15 | Largest source of Molybdenum in the world exists in Colorado.<br><br>Molybdenum is an essential nutrient for all nitrogen fixing plants. Metabolism of Molybdenum is closely linked to Copper in higher life forms |

# ANNEX D

# WATER QUALITY OBJECTIVES FOR RECREATIONAL USE

ANNEX D - WATER QUALITY OBJECTIVES

FOR

RECREATIONAL USE

## Introduction

The objectives recommended to protect recreational water use are summarized in the initial table. These recommended objectives are based on a review of the references listed, and our professional judgement. We have assumed there will be no significant discharges of domestic wastes directly to the surface waters of the Poplar Waterway in the reasonably foreseeable future.

PROPOSED WATER QUALITY OBJECTIVES FOR RECREATIONAL USE

| Parameter | Level |
| --- | --- |
| Fecal Coliforms | No objective set due to lack of evidence of significant risk. |
| pH | Minimum greater than 6.5<br>Maximum not more than 0.5 greater than natural |
| Total Coliforms | No objective set due to lack of evidence of significant risk. |

## FECAL COLIFORMS

### Recommended Objectives

| Recommended Objectives | | REFERENCES |
|---|---|---|
| 200 organisms/100 mls for 14 states, $8 \times 10^5$ organisms/100 ml by MPN before significant risk. | 1. | A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S. |
| No recommendation due to the paucity of valid epidemiological data. | 2. | "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973). |
| Geometric mean 200 organisms/ 100 mls. | 3. | Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| Geometric mean 200 organisms/ 100 mls. | 4. | "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment. |
| Geometric mean 200 organisms/ 100 mls 9 out of 10 samples less than 400 organisms/100 mls. | 5. | "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. | "Table 3: Chemical Water Quality Guidelines for Private Water Supplies- Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| | 7. | Water Quality Standards - $B\text{-}D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962). |
| | 8. | McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. | 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

## pH (pH units)

| Recommended Objectives | REFERENCES |
|---|---|
| Minimum 6.5 for 23 states, maximum 8.5 for 25 states, 6.5 - 8.3 average conditions. | 1. A Summary-Community Water Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U. S. |
| 6.5 - 8.3 for most waters, 5.0 - 9.0 for low buffer waters. | 2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973) |
| | 3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976). |
| | 4. "Table 2: Municipal Drinking Water Objectives, Water Quality Objectives, Saskatchewan Environment |
| 6.5 - 8.3 except if due to natural causes. | 5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment. |
| | 6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment. |
| | 7. Water Quality Standards -B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to: Drinking Water Standards, U.S. Department of Health, Education and Welfare (1962). |
| | 8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963). |
| | 9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date. |

# TOTAL COLIFORMS

## Recommended Objectives

1 000 organisms/100 for 22 states $8 \times 10^5$ organisms/100 ml by MPN before significant risk

No recommendation due to the paucity of valid epidemiological data.

Geometric mean 1 000 organisms/100 mls. Maximum 2 400 organisms/100 mls.

## REFERENCES

1. A Summary-Community Purveyor Responsibilities under the Safe Drinking Water Act, (Public Law 93-523), U.S.

2. "Public Water Supplies", Water Quality Criteria 1972, EPA, R3-73-033, (March 1973).

3. Quality Criteria for Water, U.S. Environmental Protection Agency (July 1976).

4. "Table 2: Municipal Drinking Water Objectives", Water Quality Objectives, Saskatchewan Environment.

5. "Table 1: Surface Water Quality Objectives", Water Quality Objectives, Saskatchewan Environment.

6. "Table 3: Chemical Water Quality Guidelines for Private Water Supplies-Poor Quality (i.e., upper range fit for consumption)", Water Quality Objectives, Saskatchewan Environment.

7. Water Quality Standards -B-$D_2$ Classification, Montana Department of Health and Environmental Sciences, (September 1974) and reference to:

   Drinking Water Standards, U.S. Department of Health, Education, and Welfare (1962).

8. McKee and Wolf: "Potential Pollutants" Water Quality Criteria, State Water Quality Control Board, California, Publication No. 3-A, (February 1963).

9. 1978 Guidelines for Canadian Drinking Water Quality, "Criteria Reviews", unpublished to date.

# ANNEX E

# METHODOLOGIES FOR THE APPLICATION OF WATER QUALITY OBJECTIVES

## ANNEX E

## METHODOLOGIES FOR THE APPLICATION OF WATER QUALITY OBJECTIVES

### Introduction

The chemical, physical and biological characteristics of water are determined usually by collection and examination of water samples. The way in which water samples are collected and handled has an important bearing on the results of their examination. The analytical methodologies used in the examination of water have an important bearing on the reliability and comparability of results.

The committee is concerned with the production of reliable and comparable analytical results in the application of water quality objectives for the Poplar River Basin.

### Sampling, Preservation and Handling of Water Samples

The sampling of water, its preservation and its care during handling require careful attention as the results of any physical, chemical and biological investigations are only as good as the water received for analyses.

It is because good sampling and handling techniques are important in the application of water quality objectives for this basin the Committee makes the following recommendations:

1. Selection of Sampling Site--that each site be carefully selected so as to ensure an overall plan for evaluating water quality on a broad basis and that each site gives information that can be correlated with periodic information at other sites.

2. Methods of Sampling--that the samples obtained be truly representative of the water body being sampled by following the procedures detailed in references 1, 2, 3, and 4.

3. Preservation of Samples--that satisfactory analytical results be assured by closely following the instructions detailed in references 2 and 4.

4. Indentification and Shipping of Samples--that samples be properly identified and field sheets completed on site and that samples be shipped to ensure receipt in laboratories in good condition for analyses.

## Analyzing Water Samples

The analytical methods selected for determining the quality of the water in the basin must be comparable among water laboratories in Canada and in the United States of America. This is imperative when making assessments of water quality in relation to basin and boundary water quality objectives.

In order to achieve these required results, the Committee recommends that:

1. Standard Methods for the Examination of Water and Wastewater, 14th Edition (1) be used for all examinations of surface waters and groundwaters.

2. All laboratories participating in the analyses of the waters of this basin also participate in a National Laboratory Quality Control Program for water.

## References


1. American Public Health Association, American Water Works Association and Water Pollution Control Federation, 1976. Standard Methods for the Examination of Water and Wastewater, 14th Edition. American Health Association, 1015 Eighteenth St., N.W., Washington, D.C. 20036.

2. American Society for Testing and Materials, 1976. Annual Book of ASTM Standards, Part 23. Water: Atmospheric Analysis. 1916 Race St., Philadelphia, Pa. 19103.

3. Hem, John D., 1959. Study and Interpretation of the Chemical Characteristics of Natural Water. Geol. Survey, Water Supply Paper 1473, U.S. Dept. of the Interior. Super. of Documents, U.S. Gov. Printing Office, Washington, D.C. 20402.

4. Rainwater, F.H. and L.L. Thatcher, 1960. Methods of Collection and Analysis of Water Samples. Geol. Survey, Water Supply Paper 1454, U.S. Dept. of the Interior. Super. of Documents, U.S. Gov. Printing Office, Washington, D.C. 20402.

ANNEX F

GLOSSARY OF SELECTED TERMS

## GLOSSARY OF SELECTED TERMS

ACUTE: involving a stimulus severe enough to rapidly induce a response; in bioassay tests, a response observed within 96 hours typically is considered an acute one.

ANTAGONISM: the power of one toxic substance to diminish or eliminate the toxic effect of another; interactions of organisms growing in close association, to the detriment of at least one of them.

APPLICATION FACTOR: a factor applied to a short-term or acute toxicity test to estimate a concentration of waste that would be safe in a receiving water.

BACKGROUND: the abundance of a substance in a water in which the concentration is consistent with what would naturally be expected.

DIFFUSED WASTE SOURCE: a general, unconfined waste discharge; run-off.

DIURNAL: daily.

EXCHANGE COMPLEX OF SOILS AND SEDIMENTS: the exchange of cations held by soil-adsorbing complex with other cations.

FLOW-WEIGHTED MEAN: sum of like products of flow times the concentration at that flow divided by the total flow.

HISTORICAL: the history of a substance in any water in which the concentration is consistent with what would be expected due to past events.

LETHAL: involving a stimulus or effect causing death directly.

MEDIAN LETHAL CONCENTRATION ($LC_{50}$): the concentration of a test material that causes death to 50 percent of a population within a given time period.

MULTIPLE PURPOSE OR MULTIPLE-USE: the multiple use of water for natural and/or man's purposes.

NATURAL WATER QUALITY: water that is near equilibrium with its environment. In its characteristics it expresses the full effects of the forces of climate, living matter and man's present activities.

PARAMETER: one of a set of chemical, physical, biological, or radiological properties whose values determine the characteristics of a water system.

PHYTOTOXIC: poisonous to plants.

POINT WASTE SOURCE: any discernible, confined and discrete conveyance such as any pipe, ditch, channel, tunnel or conduit from which pollutants are or may be discharged.

SAFETY FACTOR: a numerical value applied to short-term data from other organisms in order to approximate the concentration of a substance that will not harm or impair the organism being considered.

SUBACUTE: involving a stimulus not severe enough to bring about an immediate response.

SUBLETHAL: involving a stimulus below the level that causes death.

SYNERGISM: interactions of two or more substances or organisms that act together to produce an increased effect.

TOXICANT: a substance which will cause injury to living tissue once it reaches a susceptible site in or on an organism.

WATER QUALITY CRITERIA: the scientific information used to assess the effects of parameter on a particular water use.

WATER QUALITY OBJECTIVE: the level of a parameter which is determined as acceptable for a particular water use.

ATTACHMENT 1

# RECOMMENDED NUMERIC CRITERIA
# AT INTERNATIONAL BOUNDARY
# POPLAR RIVER BASIN

April 1979

Mike Watson
Water Uses and Water Quality Objectives
Committee, Poplar River Water Quality Board

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SUMMARY

Careful consideration was given to the preparation of this separate report from the Poplar River Water Uses and Objectives Committee of the Poplar River Water Quality Board. The report was prepared by a single U.S. Committee Member and is presented as an alternative to the majority findings and recommendations of the full committee. It is respectfully submitted that the principal reasons for the preparation of a separate report are as follows:

(1) the Committee failed to consider all interests in real property that would be damaged by water quality degradation.

(2) the Committee failed to consider salinity criteria from other international agreements, from a comparable and recent investigation by the IJC of Manitoba rivers, and the Committee erred in citing water quality criteria.

(3) the Committee did not distinguish between the need for higher numeric criteria at the international boundary and water quality objectives for all uses in the basin.

(4) the Committee did not provide for the equitable sharing of water quality degradation by both countries.

(5) the presence of Cookson Reservoir and the ongoing construction by SPC was an influence on the Committee and resulted in the determination of water quality objectives that would accomodate the SPC development.

Also it was felt that the limited discussions of damages by the Committee that would result from water quality degradation are outside the jurisdiction of the reference of the IJC to the Board and the Board to the Committee. Secondly, the discussions of the extent of damages do not cover the entire basin, are speculative and conjectural in some cases, and are purely spurious in other cases.

Finally, it was felt that the surface water quality modelling, (the responsibility of another Committee), produces results substantially in error. Historic sampling of water quality reveals substantially higher salinity at the international boundary than predicted by the model. Therefore, it was considered imperative to develop a rationale, as herein presented, that would permit considerations of water quality objectives aside from an interpretation of the model.

I

## IDENTIFICATION OF REAL PROPERTY INTERESTS IN POPLAR RIVER

The Committee accomplished substantial work in the identification of existing water uses in the Poplar River Basin. However, the existing water uses do not constitute all interests in real property in the waters of the Poplar River. The Fort Peck Sioux and Assiniboine Tribes currently have substantial real property interests in the Poplar River. The nature of those interests are summarized recently by a U.S. Federal Court:

> "In Winters v. United States, 207 U.S. 564, 28 S.Ct. 207, 52 L.Ed. 340 (1908), the Supreme Court established the doctrine of implied reservation of water. The Court determined that when the United States set aside lands as Indian reservations, it intended to provide a suitable homeland for the Indians so they could change from their nomadic ways to "become a pastoral and civilized people." Id. at 576, 28 S.Ct. at 211. As recently noted by the Supreme Court, "It can be said without overstatement that when the Indians were put on these reservations they were not considered to be located in the most desirable area of the Nation." Arizona v. California, 373 U.S. 546, 598, 83 S.Ct. 1468, 1497, 10 L.Ed.2d 542 (1963). The creators of the western reservations were aware of the arid nature of the region, and of the fact that water is "essential to the life of the Indian people and to the animals they hunted and the crops they raised." Id. at 599, 83 S.Ct. at 1497. When Congress placed the Indians on reservations, it took from them "the means of continuing their old habits" and therefore must have intended to give them "the power to change to new ones." Winters, supra, 207 U.S. at 577, 28 S.Ct. at 212. Because the reservation lands were arid and were "practically valueless" without irrigation, the Winters Court held that the Indians were entitled to an adequate supply of water.

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> [1-5] As defined in Cappaert v. United States, 426 U.S. 128, 138, 96 S.Ct. 2062, 2069, 48 L.Ed.2d 523 (1976), the Winters reserved water rights doctrine provides that upon the establishment of any federal reservation the United States "reserves appurtenant water then unappropriated to the extent

needed to accomplish the purpose of the reservation." The Winters reserved water right vests on the date of the reservation and is superior to the rights of future appropriators." Id. Winters rights apply to reservations created by executive order, as well as to those created by treaty or act of Congress. Arizona v. California, supra, 373 U.S. at 598, 83 S.Ct. 1486. They extend to ground water as well as surface water. Cappaert, supra, 426 U.S. at 142-143, 96 S. Ct. 2062. Where the purpose of establishing the reservation was to turn the Indians into an agrarian society, as is the case with the Colville Reservation, the amount of water impliedly reserved is that which would satisfy future as well as present needs, measured in terms of enough water to irrigate "all the practicably irrigable acreage" on the reservation. Arizona v. California, supra, 373 U.S. at 600, 83 S.Ct 1468. The reserved rights are open-ended and do not depend on actual use to be maintained. Water is therefore available whenever needed to fulfill the purposes of the reservation. The reserved amount of water must be made available despite inequities to the non-reserved users. Cappaert, supra, 426 U.S. at 138, 96 S.Ct. 2062. Therefore, reserved water rights are not lost by laches, estoppel or adverse possession. See United States v. Ahtanum Irr. Dist., 236 F.2d 321 (9th Cir. 1956), cert. denied, 352 U.S. 988, 77 S.Ct. 386, 1 L.Ed.2d 367 (1957), rev'd., 330 F.2d 897 (9th Cir.), rehearing denied, 338 F.2d 307 (9th Cir. 1964), cert. denied, 381 U.S. 924, 85 S.Ct. 1558, 14 L.Ed.2d 683 (1965)." 1/ (Emphasis supplied)

The Committee was not directed by the Board in the "terms of reference" to recommend water quality objectives insuring that impacts on water quality of SPC operations and water apportionment will not cause injury to property in the United States. In the absence of direction to investigate injury to property, the Committee did not report the water quality impacts on the reserved waters of the Fort Peck Tribes. The

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1/ 460 Federal Supplement 1320 (1978).

Committee failed to consider injury to property other than that associated with existing uses. Consequently, the Committee failed to address Article IV of the Boundary Waters Treaty of 1909, which reads in part as follows:

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

## II

## ERROR IN DETERMINING WATER QUALITY OBJECTIVES FOR TOTAL DISSOLVED SOLIDS

The Committee examined objectives for total dissolved solids from numerous sources and for a variety of purposes. The following summarizes the Committee findings:

| Purpose | TDS Objectives |
|---|---|
| Municipal & Domestic | None Given |
| Biota | Not to Exceed 2500 mg/l (p. 122) |
| Agriculture | |
| Livestock | Not to Exceed 3000 mg/l (p. 140) |
| Irrigation | 500 to 5000 mg/l (p. 142) |
| Industrial | None Given |

The Committee report failed to include total dissolved solids objectives for drinking water. As previously recognized by the IJC:

> "TDS concentrations in excess of 500 grams per cubic metre (g/m$^3$) cause taste problems in drinking water..." 2/

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2/ International Joint Commission, Canada and United States, 1977; Transboundary Implications of the Garrison Diversion Unit, An IJC Report to the Government of Canada and the United States (p. 42).

The Committee report failed to include objectives for total dissolved solids for industrial purposes. Also, as recognized by the IJC:

> "...concentrations between 500 and 1000 $g/m^3$ can cause foaming in boilers and interference with clearness, colur or taste of finished industrial products..." 3/

The Committee was advised that the principal consumptive use within the Fort Peck Indian Reservation would be irrigation. The Committee was also advised that the Poplar River is the source of supply for coal development and subsequent power generation associated with the 500 million tons of low sulphur lignite reserves in the Fort Kipp, Medicine Lake, and Reserve fields. These fields are located within the reservation between the Poplar and Big Muddy rivers. 4/ Further rural and municipal water systems, including the town of Poplar, will also rely on the Poplar River as a source of supply. By failing to consider water quality objectives for drinking water and industrial purposes such as coal-fired electrical generation, the Committee did not:

> "...assure protection of the most sensitive water use..." 5/

Respecting irrigation water quality objectives for total dissolved solids, the Committee cited references that differ substantially from actual practice and have no force or effect in actual management of river systems in the United States. For example, the Committee cites

> "Water Quality Criteria 1972, NAS-NAE, Washington, D.C. p. 333" 6/

for total dissolved solids in the Colorado River Basin as ranging from 100 to 2500 milligrams per liter (grams per cubic meter). It is

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3/ Ibid.

4/ Fort Peck Sioux and Assiniboine Tribes, November 1978; Poplar River Existing and Future Uses, Fort Peck Indian Reservation, Montana. (Appendix B, p. 7).

5/ Water Uses and Water Quality Objectives Committee, 1979; Draft, International Poplar River Water Quality Board, Appendix D, p. 42.

6/ Ibid, p. 142.

stressed, here, that these data which were used by the Committee do not constitute water quality criteria in the Colorado River, an international stream which flows out of the southern United States into Mexico.

To amend the serious error of the Committee and to cite international precedent for water quality objectives, reference is made to the Colorado River. The Colorado River Basin Salinity Control Forum recently reported as follows:

> "Below Imperial Dam, the river's salinity will be controlled to meet the terms of the agreement with Mexico on salinity in Minute 242 of the International Boundary and Water Commission, entitled "Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River." This agreement states that measures will be taken to assure that the waters delivered to Mexico upstream from Morelos Dam will have an annual average salinity of no more than 115 ppm (± 30 ppm) total dissolved solids greater than the annual average salinity of Colorado River water arriving at Imperial Dam. Title I of P.L. 93-320 is the legislation which implements the provisions of Minute 242. Minute 242 and Title I constitute a federal numeric criterion and plan of implementation for the river below Imperial Dam." 7/

The numeric criteria at Imperial Dam for total dissolved solids (salinity) is 879 milligrams per liter. 8/ The increase in salinity of 115 milligrams per liter greater than the numeric criteria at Imperial Dam results in a water quality objective of 994 milligrams per liter at the U.S. - Mexican international boundary. The use by Mexico is in the extreme lower portion of the basin and the objectives at the international boundary is adequate to protect downstream uses, all of which are immediately below the boundary.

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7/ Colorado River Salinity Control Forum, August 1978; Proposed 1978 Revision, Water Quality Standards For Salinity Including Numeric Criteria and Plan of Implementation For Salinity Control, Colorado River System, pp. 2 and 3.

8/ Ibid, p. i.

An objective for total dissolved solids applicable for drinking water, industrial use and irrigation was considered by the International Joint Commission in its study of Garrison Diversion Unit. The Committee failed to cite the conclusions from this extensive investigation involving international water quality objectives for the Souris River, which is located east of the Poplar River in the same geographic region. The IJC arrived at its conclusion on the Souris River based on similar condition of climate, geologic history, soils and agricultural production. The conclusion of the IJC was as follows:

> "The proposed TDS objective for the Souris and Red Rivers in Manitoba is a desirable concentration of 500 $g/m^3$ and an acceptable concentration of 1000 $g/m^3$ for flows less than 140 cubic feet per second (cfs) or 7 cubic metres per second ($m^3/s$). At higher flows the desirable and acceptable concentrations are lower." 9/

It is inconceivable that water quality objectives could vary so substantially between the Poplar River and Souris River. It is recommended here that 1000 milligrams per liter be established as the water quality objective for total dissolved solids in the Poplar River Basin. The objective of 1000 miligrams per liter is at the poor end of the range selected by the IJC for the Souris River and at the better end of the range recommended by the Committee.

The Committee recommended as follows:

> "1) the long-term (10-year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1000 milligrams per litre, and
>
> 2) the short-term (any 3-consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 1500 milligrams per litre." 10/

An allowance of 90 days of total dissolved solids at an average level of 1500 milligrams per liter is a substantial degradation beyond the IJC recommendations for the Souris River. The allowance, while

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9/ See note 2, p. 43.
10/ See note 5, supra, p. 62.

referred to as "short-term", covers an extended period of time, and the allowance is made during the period of principal use of water.

The degradation in water quality proposed for the Poplar River to 1500 milligrams per litre total dissolved solids substantially exceeds the "acceptable concentration" of 1000 milligrams per litre recommended by the IJC for the Souris River: An objective for total dissolved solids of 1000 milligrams per litre is compatible with the objectives for the Souris River and the Colorado River. It is recommended that an objective for total dissolved solids of 1000 milligrams per litre for the Poplar River extend to all months of the year.

## III

## <u>FAILURE TO ESTABLISH NUMERIC CRITERIA AT INTERNATIONAL BOUNDARY TO "PROTECT DOWNSTREAM USES"</u>

The Committee attempted to establish multipurpose water quality objectives for the

> "BASIN INCLUDING INTERNATIONAL BORDER CROSSINGS" 11/

In the previous section reference was made to the Treaty between the United States and Mexico whereby the United States provides Mexico with water having a total dissolved solids concentration of 994 milligrams per liter or water of higher quality. Water of the quality specified is diverted by Mexico at the Morales Dam at the international boundary. The Morales Dam is the sole and exclusive diversion of the Colorado River by Mexico. It utilizes the entire flow of the river at most times, and there are no additional downstream diversions.

In the case of the international agreement between the United States and Mexico on the Colorado River, a reasonable "water quality objective for uses" in Mexico coincides with "numeric criteria" at the international boundary, but only because Mexico is the most downstream water user in the basin, and Mexico's sole point of diversion is at the international boundary.

In the Poplar River Basin, however, the international boundary is far upstream from the lowest point of use in the basin. The international boundary divides the basin such that approximately one-third of the watershed area lies in Canada and two-thirds lies in the United States. 12/ The most downstream water user in the basin is the resident Indian of the Fort Peck Reservation. As cited in Section 1, the Fort

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11/ See note 2 supra, p. 54.

12/ The watershed area of the West Fork, Middle Fork and East Fork Poplar Rivers at the international boundary total 788 square miles, compared with the watershed area of the Poplar River near Poplar of 2891.6 square miles. The long-term average annual streamflow of the West Fork, Middle Fork and East Fork Poplar Rivers totals 29,235 acre-feet compared with the Poplar River near Poplar which totals 92,560 acre-feet. (International Souris-Red Rivers Engineering Board, Poplar River Task Force, February 1976; <u>Joint Studies For Flow Apportionment, Poplar River Basin in Saskatchewan and Montana, Main Report</u>, p. 12).

Peck Tribes have water rights that are "superior" to appropriators of water after 1888, the date of establishment of the reservation. 13/ Because the Fort Peck Tribes are (1) the most downstream water users and (2) have "superior" water rights to appropriators after 1888, it is manifest that "numeric criteria" at the international boundary be established adequate to insure that "water quality objectives of the most downstream user are satisfied, and hence damages to the property rights of the most downstream user are not incurred.

The water quality evidence that was collected for the Poplar River is presented in Table 1. The evidence clearly demonstrates that the salinity of the Poplar River generally increases between the international boundary and the most downstream points of diversion. 14/ The increasing stream flow between the international boundary and the downstream user does not dilute or otherwise diminish the salinity of the river, and in general the gain in streamflows results in an increase in salinity.

The consequence of the natural increases in levels of salinity (or lack of natural dilution) between the international boundary and the most downstream diversion point is to require "numeric criteria" at the boundary that are higher than "water quality objectives" at the downstream points of diversion. Without numeric criteria at the international boundary that reflect higher water quality than the water quality objectives for uses throughout the basin, the United States would be forced to improve the water quality within its borders in order to meet water quality objectives. This would place an unequitable burden on the United States.

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13/ See note 2, supra.

14/ Salinity of the Poplar River at Poplar is representative of the salinity of the water below the confluence of the West Fork with the main stem Poplar River. The watershed area of the Poplar River above the West Fork (1742.1 square miles, Poplar River near Kahla) and of the West Fork above its mouth (1010 square miles, West Fork Poplar River at the mouth) totals 2752.1 square miles. The watershed area of Poplar River at Poplar is 2981.6 square miles. The reach of stream between the confluence of the West Fork with the Poplar River and the town of Poplar is the area of diversion for water uses within the reservation.

TABLE 1

COMPARISON OF HISTORIC MEASUREMENTS OF TOTAL DISSOLVED SOLIDS (MILLIGRAMS PER LITER) AT INTERNATIONAL BOUNDARY AND NEAR MOUTH 15/

| YEAR/MONTH | INTERNATIONAL BOUNDARY WEST FORK | MIDDLE FORK | EAST FORK | POPLAR RIVER AT POPLAR |
|---|---|---|---|---|
| 1975 | | | | |
| October | -- | -- | 936 | -- |
| November | -- | -- | 1,180 | -- |
| December | -- | -- | 1,180 | 1,280 |
| 1976 | | | | |
| January | -- | -- | 927 | -- |
| February | -- | -- | 901 | -- |
| March | -- | -- | 97 | 620 |
| April | -- | -- | 194 | 356 |
| May | -- | -- | 875 | -- |
| June | -- | -- | -- | 663 |
| July | 855 | 511 | 956 | 594 |
| August | 899 | 865 | 891 | 905 |
| September | 861 | 1,070 | 997 | 982 |
| October | 870 | 942 | 936 | 963 |
| November | 1,070 | 678 | 927 | 965 |
| December | 1,330 | 898 | 919 | 1,230 |
| 1977 | | | | |
| January | 1,230 | -- | 959 | 1,460 |
| February | 1,250 | -- | 925 | 1,500 |
| March | 645 | 740 | 873 | 787 |
| April | 478 | 698 | 862 | 902 |
| May | 809 | 900 | 949 | 1,000 |
| June | 1,100 | 948 | 1,060 | 1,010 |
| July | 1,020 | 1,140 | 833 | 1,350 |
| August | 976 | 1,110 | 888 | 1,870 |
| September | 1,010 | 1,160 | 898 | 1,480 |

15/ Values are results of sampling and are published: U.S. Geological Survey, Water Resources Data For Montana, Water Years 1975, 1976, and 1977; data are same as used by Poplar River Water Quality Board in its investigations of the Poplar River.

Again referring to the international agreement between the United States and Mexico, a solution was reached by setting numeric criterion at Imperial Dam (879 milligrams per liter, salinity) that would permit degradation (115 milligrams per liter, salinity) within the United States, but would nevertheless insure the satisfaction of the water quality objectives of Mexico, the downstream country. The United States has undertaken substantial mitigation measures to insure that the numeric criterion at Imperial Dam is met. 16/

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16/ U.S. House of Representatives resolution number 2609 seeks authorization of appropriations of $333,382,000 for implementation of the Colorado River Basin Salinity Control Act. It passed, this would increase the 1974 authorization of $155,500,000.

## IV

## PETITION TO ESTABLISH NUMERIC CRITERIA AT INTERNATIONAL BOUNDARY TO "PROTECT DOWNSTREAM USES"

The historic patterns of water quality and streamflows of the streams in Manitoba affected by the Garrison Diversion Unit are comparable to the Poplar River. The IJC found in its investigation of the Garrison Diversion Unit as follows:

> ". . .that in the rivers of the study area in Manitoba water is often in short supply and the water quality, which varies with flow fluctuations, is marginal,. . . 17/

Table 2 summarizes the salinity of the Souris River in Manitoba and the Poplar River in Saskatchewan and Montana for historic conditions. (Historic measurements of salinity of the West Fork Poplar, Poplar, and East Fork Poplar at the international boundary are markedly similar, and it should be noted that computer values for the West Fork and Poplar are included in Table 2 for completeness but are not truly representative of historic water quality at these locations.)

From Table 2 it is clear that the water quality of the Poplar River, not unlike the Souris River, is marginal. In connection with the Garrison Diversion Unit, the IJC took two views. The majority opinion of the IJC was stated as follows:

> "In the Commission's view it would be far better to approach the problem of GDU and other basin developments from the aspect of the equitable utilization of the river basin or watercourse on behalf of both countries, through a system of water quality management based on agreed objectives and standards.
>
> The obligation of the downstream country to manage the uses of its waters is encouraged by the certainty that the upstream country must preserve

17/ See note 2 supra, p. 99.

TABLE 2

HISTORIC SALINITY OF SOURIS AND POPLAR RIVERS (MEDIAN VALUES OF TOTAL DISSOLVED SOLIDS IN MILLIGRAMS PER LITER)

| Month | Souris At Westhope[18/] | E. Poplar At Boundary[19/] | Poplar At Boundary[20/] | W. Poplar At Boundary[20/] | Poplar At Poplar[19/] |
|---|---|---|---|---|---|
| January | 1,295 | 1,470 | 780 | -- | 1,240 |
| February | 1,560 | 1,290 | 730 | -- | 1,280 |
| March | 483 | 250 | 550 | 460 | 470 |
| April | 390 | 340 | 530 | 470 | 510 |
| May | 429 | 560 | 600 | 680 | 700 |
| June | 563 | 640 | 630 | 640 | 790 |
| July | 546 | 680 | 700 | 680 | 1,020 |
| August | 495 | 770 | 710 | 670 | 1,280 |
| September | 531 | 720 | 720 | 650 | 1,250 |
| October | 725 | 700 | 700 | 750 | 1,010 |
| November | 702 | 830 | 730 | 720 | 1,010 |
| December | 937 | 1,070 | 780 | -- | 1,190 |

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18/ Ibid, p. 74.
19/ Source: Computer runs of Surface Water Quality Committee, Scenario number 2; data are reasonably compatible with historic measurements of salinity.
20/ Source: Computer runs of Surface Water Quality Committee, Scenario number 2; computer runs in error show substantially lower values of salinity than historic measurements of salinity.

a level of quality over which there will be no need for concern as that water crosses the boundary. A new sense of mutuality of interest thus is developed and it is expressed by the maintenance of agreed water quality objectives throughout the length of the river. This is not a requirement of the Boundary Waters Treaty but rather is a conception that goes beyond that Treaty; and this recommendation in no way affects or is affected by the recommendation of the Commission with respect to GDU itself since the Commission is making this recommendation with respect to a Water Quality Agreement in and for itself." 21/ (Emphasis supplied)

A second opinion was given by Commissioner Bernard Beaupre' as follows:

"This, in my view, goes beyond the Boundary Waters Treaty. The fact is that the upstream country must respect its own water quality standards and must, at the same time, comply with the provisions of the Boundary Waters Treaty of 1909, and therefore deliver at the point where the river crosses the Boundary, water which will not cause injury to health and property in the downstream country. As for the downstream country, it also must respect its own water quality standards; whatever it does will, on the other hand, have no adverse effects on the upstream country if there are no major transfrontier transfers of biota upstream from activities downstream, although this will have to be monitored by a binational agency" 22/ (Emphasis supplied)

Using the latter opinion as a basis for a water quality agreement on the Poplar River, it is clear from Table 2 that in most months, any degradation of water quality at the international boundary will cause downstream degradation to the irreparable damage of property

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21/ See note 2, supra, p. 118.
22/ Ibid, p. 127.

rights of users between the mouth of the Poplar River and the West Fork confluence. During the late summer, fall and winter, salinity of the Poplar River at Poplar exceeds an acceptable salinity level of 1000 milligrams per liter for agricultural, municipal, rural domestic and industrial purposes (See Section II). Degradation of the East Fork Poplar River below historical levels will only further raise the salinity level downstream and will cause injury to downstream property.

In the months of March, April, May and June, historic salinity levels do not exceed an acceptable water quality objective for salinity of 1000 milligrams per liter. In these months some degradation at the international boundary would be permissible until the downstream salinity was raised to 1000 milligrams per liter, and injury would result thereafter. However, when the salinity exceeds 1000 milligrams per liter under historic conditions, further degradation by the upstream country requires increased mitigation to the damage of the downstream country.

It is therefore submitted that the upstream country be required to provide water at the international boundary with no more salinity than was experienced historically, except in the months of March through June, if a view compatible with Commissioner Beaupre' is taken.

In the case of the majority opinion of the IJC on Garrison as cited above, a different view was taken which encourages the downstream country to manage its water because the upstream country must preserve a level of water quality at the boundary that will not cause downstream concern. It is respectfully submitted that the only practical and equitable solution of establishing a numeric salinity criteria at the boundary would be as follows:

> to share in the level of degradation between historic salinity levels and an acceptable level of 1000 milligrams per liter

A practical management criteria for salinity has been developed and is submitted, in Table 3 for the East Fork Poplar River. The historic salinity was based on the relationship between total dissolved solids and discharge from measured data. The recommended salinity provides for an equal sharing of the degradation between historic salinity and acceptable salinity. Within its borders, Canada could utilize water of any quality up to or greater than 1000 milligrams per liter for any purpose, provided water quality as recommended in Table 3 is supplied at the boundary. Water at the boundary would be

of higher salinity than experienced historically, and the United States would have to mitigate accordingly to use the water downstream or would suffer damages. The damages, however, would not be accounted to Canada if salinity criteria at the boundary were being met.

TABLE 3

RECOMMENDED SALINITY CRITERIA
FOR EAST FORK POPLAR RIVER AT INTERNATIONAL
BOUNDARY (MILLIGRAMS PER LITER)

| Discharge (cfs) | Historic Salinity | Poplar Basin Salinity Objective | Recommended Boundary Salinity |
|---|---|---|---|
| 5 | 950 | 1,000 | 975 |
| 10 | 930 | 1,000 | 965 |
| 50 | 890 | 1,000 | 945 |
| 100 | 870 | 1,000 | 935 |
| 500 | 820 | 1,000 | 910 |
| 1,000 | 800 | 1,000 | 900 |

Recommendation for the Middle Fork Poplar River based on an equal sharing of the degradation at the boundary are summarized in Table 4.

TABLE 4

RECOMMENDED SALINITY CRITERIA
FOR MIDDLE FORK POPLAR RIVER
AT INTERNATIONAL BOUDARY
(MILLIGRAMS PER LITER)

| Discharge (cfs) | Historic Salinity | Poplar Basin Salinity Objective | Recommended Boundary Salinity |
|---|---|---|---|
| 1 | 950 | 1,000 | 975 |
| 5 | 810 | 1,000 | 905 |
| 10 | 750 | 1,000 | 875 |
| 50 | 610 | 1,000 | 805 |
| 100 | 550 | 1,000 | 775 |

For the upstream country to be allowed at the international boundary to match or exceed the salinity objective of the basin would be totally unjust and unequitable to the downstream country. The downstream country would be forced to upgrade water quality for its uses even though the upstream country was enjoying historical water quality and was responsible for the degradation of quality available for the downstream country.

For both countries to share equally in degradation to an acceptable water quality at the boundary permits each country flexibility for water uses within its borders. Both countries share in the burden for depletion of water supply and degradation of water quality. It is respectfully submitted that this approach is the only equitable conclusion to the IJC philosophy expressed in its findings related to the Garrison Diversion Unit, as cited above.

The implementation of the recommendations outlined in Tables 3 and 4 would not be difficult. Referring, for example, to Table 4, salinity of 775 milligrams per liter would be required for flows greater than 100 cfs. Flows greater than 50 cfs and less than 100 cfs would require a salinity limit of 805 milligrams per liter; and similarly for lower flows. The quantity of stream flow reaching the boundary would be specified by apportionment, and the quality would be specified according to the schedule of Tables 3 and 4.

V

## CONSTRUCTION OF COOKSON DAM DOES NOT DICTATE WATER QUALITY OBJECTIVES TO ACCOMODATE SPC

In consideration of the water quality impacts of the Garrison Diversion Unit, the IJC found that a negotiated water quality agreement was reasonable under the circumstances:

> "The approach under Article IV of the Boundary Waters Treaty is to simply forbid pollution to the injury of health or property. This requires a frequent determination of "pollution", of "injury", of "health" and of "property" and thus inevitably invites disputes over law and fact,..........The emerging doctrine of prior notice and consultation combined with the opportunity to initiate an investigation of an actual or potential conflict, that is a Reference under Article IX of the Treaty, is, of course, available.
>
> While Article IV, therefore, is one approach, it has tended to be "after the fact" and does not envisage any prior joint planning of a shared transboundary water resource where each partner may be upstream in some cases and, in others, downstream." 23/

The upstream country, the United States, had approached Canada as follows:

> "The Government of the United States has reached no final conclusion as to whether the Garrison Diversion Unit, as presently envisaged, would be consistent with the rights of the United States and of Canada to the equitable use of waters crossing the boundary, and with Article IV of the Boundary Waters Treaty....The Government of the United States has assured the Government of Canada that

23/ See note 2, supra, p. 117.

in any development of features of the Garrison Diversion Unit that will affect Canada, specifically works in the Red River Basin and the Souris Loop, the United States will comply with its obligation to Canada not to pollute water crossing the boundary to the injury of health or property within Canada. The Government of the United States has similarly assured the Government of Canada that no construction potentially affecting waters flowing into Canada will be undertaken unless it is clear that this obligation will be met." 24/ (Emphasis supplied)

Throughout the investigations of Poplar River Water quality objectives, The Committee took the view that because Saskatchewan Power Company has expended substantial sums in construction to date and "because the dam is in" water quality objectives should be developed to accomodate SPC.

That thinking is rejected here. SPC did not choose to initiate "prior notice and consultation" but proceeded with construction rather than assuring the downstream country "that no construction potentially affecting waters flowing into . . . will be undertaken unless it is clear that this obligation will be met." SPC apparently proceeded because short-term electrical shortages were anticipated and because the feasibility of its operations would not be substantially impacted if a non-degradation recommendation from IJC was forthcoming.

It is only with a view that the upstream country is proceeding in good faith that consideration of sharing of water quality objectives by both countries can be given merit. In the absence of an explicit or implied assurance to the downstream country, consideration of a non-degradation policy is of stronger force.

Mike Watson

24/ Ibid, pp. 130-131.

ATTACHMENT 2

MINORITY OPINION

WITH RESPECT TO THE RECOMMENDED BORON OBJECTIVE

POPLAR RIVER BASIN

April, 1979

Water Uses and Water Quality Objectives Committee

International Poplar River Water Quality Board

The Uses and Water Quality Objectives Committee has recommended the following boron objective for Poplar River basin waters crossing the international boundary.

Concentrations of total boron in water samples should meet the following requirements:

(1) the long term (10 year) arithmetic mean of the monthly flow weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 5.0 milligrams per litre, and
(2) the short term (any 3 consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 to September 30) should not be caused to exceed 8.0 milligrams per litre,

to protect the most sensitive use, irrigation of agricultural crops.

The decision to recommend a long term boron objective of 5.0 mg/L and a short term boron objective of 8.0 mg/L arose following an extensive review of pertinent literature and special consultation with a recognized authority on the effects of boron in irrigation waters. However, the objective limits recommended by the committee did not receive the unanimous endorsement of its members. We who oppose the majority decision are compelled to present an alternate opinion.

The Terms of Reference, as established by the International Poplar River Water Quality Board, directed the Uses and Water Quality Objectives Committee to:

1. Review and report on present and reasonably foreseeable uses of water in the Poplar River basin, particularly those of the East Poplar River. These should include but not be limited to:

    (a) Municipal and domestic potable water supply;
    (b) Irrigation, stock watering and general agricultural use;
    (c) Maintenance of indigenous fisheries;
    (d) Industrial uses; and
    (e) Contact sports and other recreational aesthetic considerations.

2. Examine the water quality criteria required to support identified uses, and develop and recommend water quality objectives to be met at the International Boundary to protect the most sensitive identified downstream water use.

3. Forecast the impact of SPC operations on water quality in relation to the recommended water quality objectives.

In response to the second article, a framework plan for formulating multi-purpose water quality objectives was developed by the committee (see pp. 42, 43 of Appendix D: Water Uses and Water Quality Objectives Committee Report).

Both the Terms of Reference and the Framework Plan depict an objective process of (a) identifying existing and foreseeable uses, (b) determining the water quality parameters likely to be affected by those uses, with particular emphasis placed on the predictive effects of the SPC operation, (c) determining the water quality requirements of each use by means of a thorough literature search coupled with sound scientific judgment, and (d) recommending water quality objectives that will protect the most sensitive use. However, we believe that a measure of subjectiveness entered into the process of developing and recommending a boron objective; that the committee's recommendation is strongly influenced

by the amount and value of a particular use, irrigated barley, which is rendered nearly insignificant when compared to the high costs of mitigating to protect that use.

Three farmers are known to irrigate barley in this basin and all three are located in Montana. Altogether, they irrigate approximately 230 acres, which is roughly 10 percent of all the full service irrigated acreage in Montana, but only one irrigator, involving 45 acres of barley, is in a part of the basin that will be directly affected by the SPC operation as it is envisaged. Nevertheless, boron in the irrigation water has a marked adverse effect on the growth of barley as its concentration exceeds a trace level. There is no argument within the committee relative to that fact. Table 1 is taken from the committee's final report.

TABLE 1. Estimated Effect of Boron on Irrigated Barley Yield

| Boron Concentration | Barley Yield Reduction* |
|---|---|
| 1.5 mg/L | 8% |
| 3.0 mg/L | 15% |
| 5.0 mg/L | 25% |
| 8.0 mg/L | 40% |

*as compared to a trace amount of boron in the irrigation water.

SOURCE: Appendix D: Water Uses and Water Quality Objectives Committee Report, Figure C-1, p. 151.

Clearly, the objective levels recommended by the majority membership of this committee will not protect irrigated barley.

The argument that boron is naturally highly concentrated in this basin is not valid to the extent that a long term average concentration of 5.0 mg/L is justified. The naturally occurring average concentration of boron in waters crossing the international boundary is in the range of 1.0 to 2.0 mg/L. The average annual concentration of boron in the East Poplar River, which is generally higher than that of the West Poplar and Poplar (middle fork) rivers, has remained within the range of 1.6 to 1.9 mg/L during the period 1975 through 1977, in spite of Cookson Reservoir. Only two samples taken monthly from the East Poplar River at the international boundary during that period exceeded 3.0 mg/L total boron (3.1 mg/L in July, 1975, and 3.7 mg/L in January, 1977). Furthermore, four samples did not exceed 1.0 mg/L.

We do not argue against the opinion that the Board and the Commission should be cognizant of the apparent disparity between the benefits and costs of protecting irrigated barley. However, if such rationale is to be used in establishing a boron objective, we believe the Commission alone possesses the legal expertise, the experience and, particularly, the authority to do so, for it inevitably requires both legal and political interpretation of the Boundary Waters Treaty, specifically Article IV.

Due to the naturally occurring levels of boron in the Poplar River basin, barley irrigators probably already suffer a 5 to 10 percent reduction in yield, as compared to ideal conditions. But, at some unknown point, be it a 15 percent, 25 percent or 40 percent reduction in yield, it is simply no longer practical to apply water to barley. The production of malting barley, for example, depends upon a delicate balance of many factors, particularly water, to produce a relatively low protein value and a pulpous kernel. If that balance is lost, the yield reduction may be more properly characterized as a 100 percent reduction.

It is recognized that dilution downstream reduces the level of boron in the water; however, a long term concentration of 5.0 mg/L total boron at the international boundary would result in an estimated average concentration of approximately 4.0 mg/L at the confluence of the East Poplar and Poplar rivers near Scobey. Barley is currently irrigated immediately below that point and an average concentration of 4.0 mg/L total boron would cause an additional 10 percent yield reduction to the existing 5 to 10 percent reduction.

Thus, any increase over natural levels of boron in this basin would adversely impact an existing use. For that reason alone, we believe that, as members of a technical committee, we have no choice but to recommend against further degradation.

D. Scott Brown

Abe Horpestad

James R. Sims